Sky and TELESCOPE

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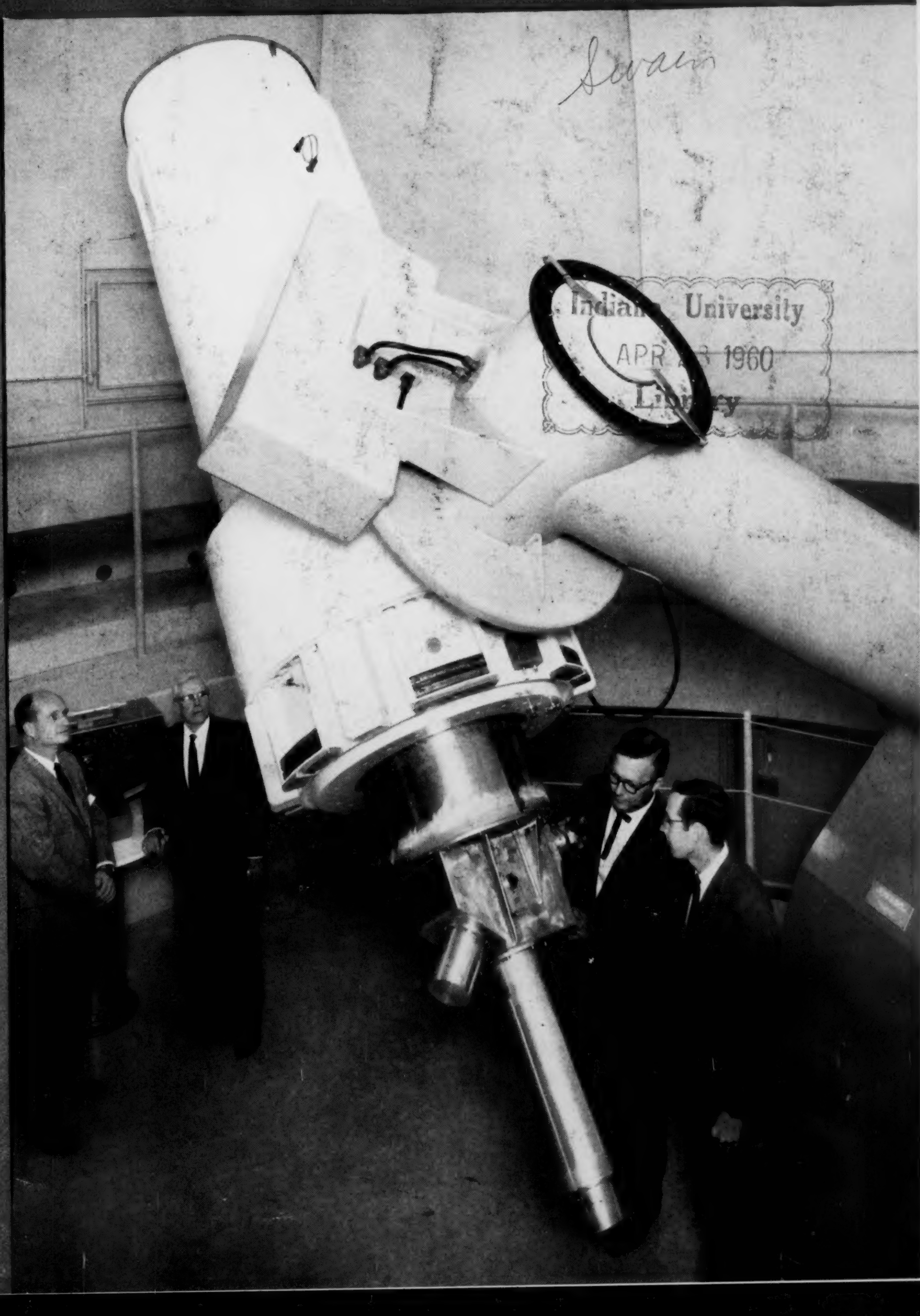
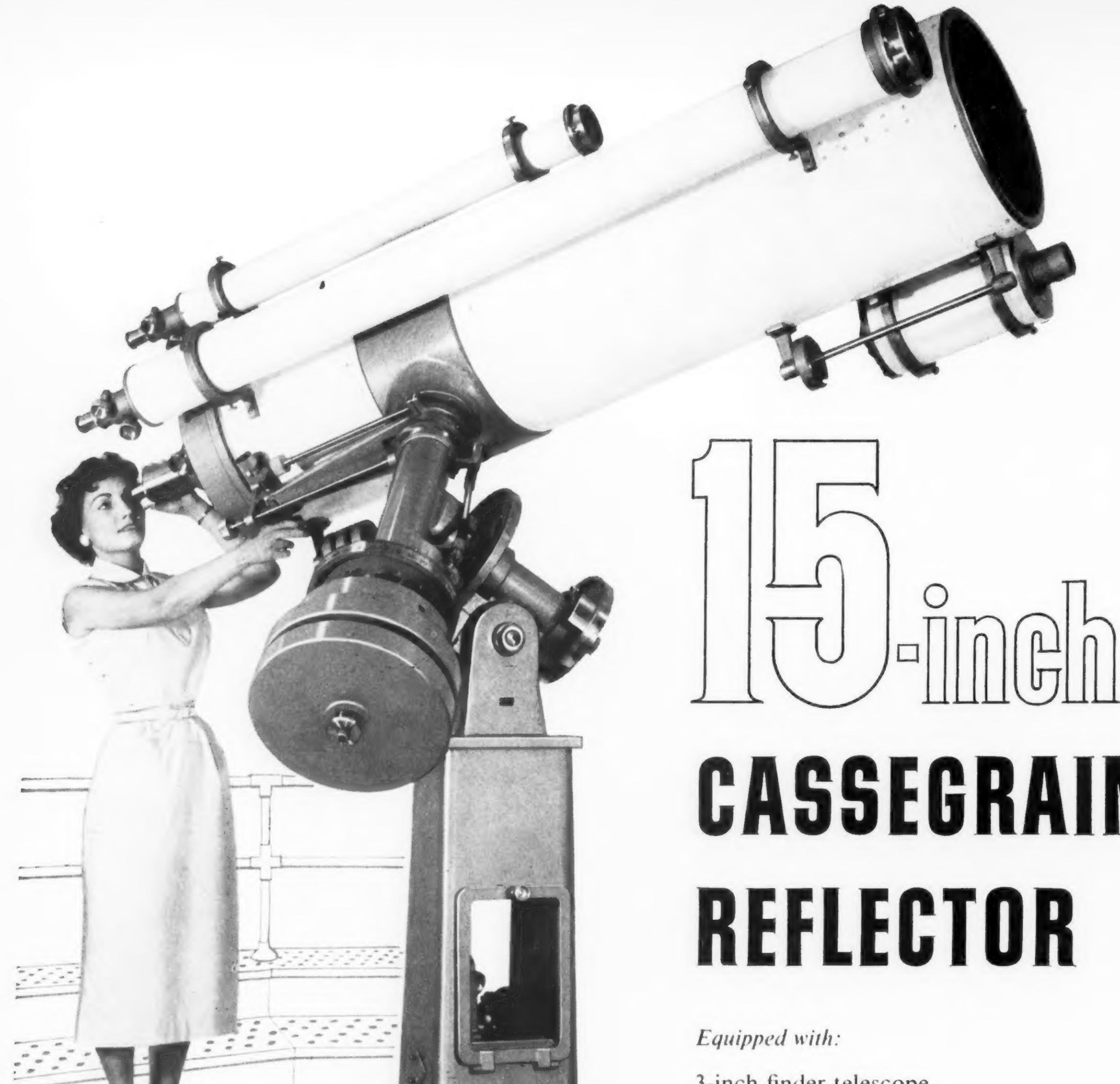


Kitt Peak Observatory 36-inch reflector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Sky and TELESCOPE

CHARLES A. FEDERER, JR., *Editor*
JOSEPH ASHBROOK, *Technical Editor*

Vol. XIX, No. 7 MAY, 1960

CONTENTS

FRONT COVER: The new 36-inch Cassegrainian reflector of Kitt Peak National Observatory, near Tucson, Arizona, at the time of the dedication of the observatory on March 15, 1960. The instrument's polar axis extends upward from the right-hand edge of the picture, but the main counterweight, located close to the upper polar-axis bearing and the hour circle, cannot be seen in this view. It is shown in the diagram on page 394. At the left, standing at the control console, are Charles W. Jones, structural engineer of the telescope, and Dr. Alan T. Waterman (dark suit), director of the National Science Foundation. Standing at the right, examining the spectrograph, are Dr. Aden B. Meinel (dark suit), the first director of Kitt Peak Observatory, and Dr. David L. Crawford, of the observatory staff. Photograph by Ray Manley. (See page 392.)

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April Cover Picture Not an Aurora?

ON MARCH 28th, Dr. Carl W. Gartlein of Cornell University, Ithaca, New York, and head of the IGY World Data Center A (Aurora Archive — Visual Observation) wrote:

"The cover photograph of aurora on SKY AND TELESCOPE for April is certainly unusual. It is the only report we have from any in our large volunteer and U. S. Weather Bureau group. The all-sky camera at Choteau, Montana, shows only a bit of aurora far to the north.

"I was suspicious of the picture the instant I saw it as the variation of intensity along the rays is quite unusual and the rays are not tilted along the magnetic field. Further, the rays at the right are interrupted. This occurs in aurora only in sunlit rays. At 10:00 p.m. Central standard time the sunlit border is too high above the earth to affect the aurora.

"The letter accompanying [from Dale P. Cruikshank, Des Moines, Iowa] also increases the doubt of auroral character since the aurora is reported only in the east and south. Further, the magnetic character was very low and our present studies indicate no possibility of aurora outside the 'auroral zone' for this magnetic number.

"I believe you have on the cover a fine photograph of columnar halos caused by the lights of the shopping center reflecting from flatly falling snow plates. These floating crystals might escape notice by an observer. If this center had mercury lights, then the auroral filter would probably indicate auroral light. In addition, the 3600-angstrom radiation would make these halo rays very effective in a photograph. The ray in the south would be from a similar light."

A second letter came from Dr. Peter M. Millman, IGY Auroral Centre, National Research Council, Ottawa, Canada, making essentially the same points as Dr. Gartlein's, and adding:

"These crystals are usually located below a height of 10,000 feet. Crystals producing the more commonly observed halo complexes of circles and arcs are generally much higher. Light pillars, though rarely seen in the southern part of the country, are not too uncommon at our northern stations in Canada. They are referred to briefly on pages 201 and 207 of the Dover edition of the book, *The Nature of Light and Colour in the Open Air*, by M. Minnaert, 1954. . . .

"The detail in the photograph you have reproduced corresponds closely to other photographs I have seen of light pillars. The pillars are actually vertical and the slight convergence toward the top of the picture is due to the camera

(Continued on page 412)

Looking southward from the summit ridge of Kitt Peak, many new structures are seen. At upper right, perched on the mountain's precipitous south rim, are the building and dome of the 36-inch reflector (see front cover), while at the extreme left, also on the south rim, rises the wall of the 84-inch telescope building. Below this, among the trees, is one of the maintenance buildings. Baboquivari Peak, 13 miles away, dominates the horizon. The long white cylinder in line with the peak is a 30,000-gallon high-pressure water-supply tank. To its right, across the road, is the present housing of the 16-inch reflector that was pictured on page 498 in the August, 1958, issue. Kitt Peak Observatory photo by J. C. Golson.

New National Observatory Dedicated at Kitt Peak

"IS THERE an intergalactic complex of stars? What are the relations between galaxies and clusters of them?"

These questions for the astronomy of the future were discussed by the chief speaker at the dedication exercises on March 15th of Kitt Peak National Observatory, the new 10-million-dollar optical observatory that is now being built on a mountaintop in southern Arizona. Already a 36-inch reflector (front-cover picture) is in operation, and an 84-inch telescope of advanced design is being built.

C. D. Shane of Lick Observatory, president of AURA, Inc., addresses the gathering at the dedication exercises on Kitt Peak. The scene is in the L-shaped dining-assembly hall, and shows only a portion of the audience. Other speakers included Robert R. McMath, of McMath-Hulbert Observatory, chairman of the AURA board and head of the original advisory panel on a national observatory, who is seated in profile at the extreme left. Between him and Dr. Shane is W. W. Morgan, of Yerkes Observatory, who gave the principal address.

The speaker was W. W. Morgan, of Yerkes Observatory and a leader in the classification of stellar spectra and the structure of the Milky Way galaxy. To an audience of more than a hundred scientists and leaders from all walks of life, he pointed out that questions like those above can be answered without building optical instruments larger than the 200-inch telescope of Palomar Observatory or the 120-inch of Lick Observatory.

Photoelectric photometry in many colors, high-dispersion spectrographs, automatic observing devices, electronic calculating machines, and especially image-intensification techniques, all now offer opportunities to make great astronomical advances with instruments of relatively moderate size.

With such equipment, Dr. Morgan is hopeful that we can eventually determine the evolutionary stages or orders of age of hundreds of thousands or millions of stars. He characterized clusters of stars as furnishing "golden avenues" to future research. He pointed out that our knowl-

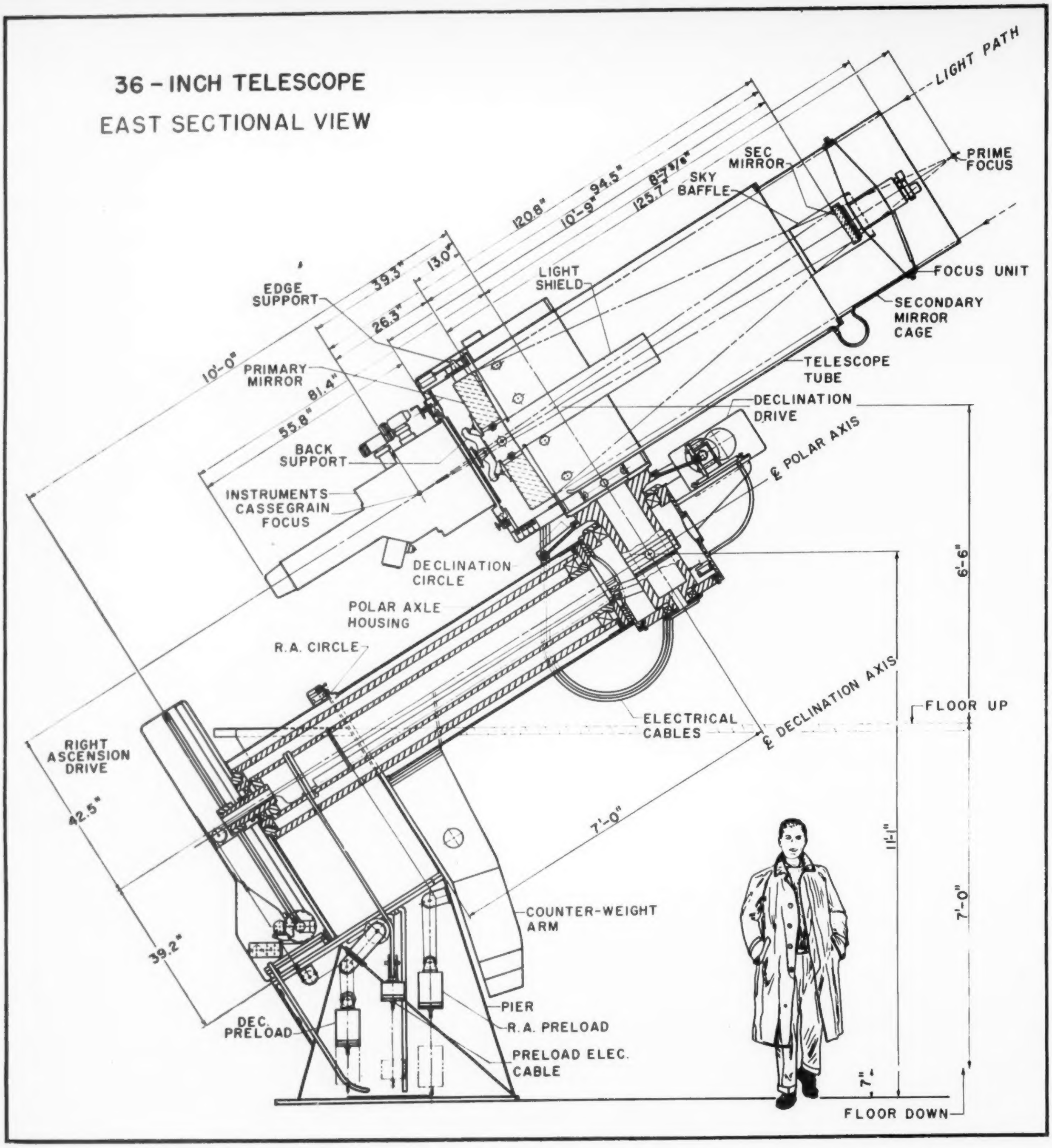
Left: Although they have themselves long been Christians, the Papago Indians regard Kitt Peak with much reverence in their tribal lore. Here Enos Francisco (left) and Harry Marcus, chairman and vice-chairman, respectively, of the Papago tribal council, are attending the dedication ceremonies. The new dome of the 36-inch reflector is seen at the upper left. Right: Physicists from Wesleyan University's Scott Laboratory are taking advantage of Kitt Peak's high altitude to do research on cosmic rays. Standing before the 16-inch telescope building are (right to left) Mr. and Mrs. Joseph Pereue, Jr., and John A. Palsedge. At each corner of an 80-meter-square area they set up a short-focus reflecting mirror and photomultiplier tube. These record the intensity of one-billionth-second flashes of Cerenkov radiation (very blue light) produced by extensive air showers of secondary cosmic rays, and indicate the zenith angle of the original high-energy particles by the differences in arrival times at the four receivers.

edge of the properties of other galaxies is still in its infancy — we especially know very little of the relations between individual systems and the gigantic clusters of galaxies that form great units in the structure of the universe as a whole.

The Yerkes astronomer noted with enthusiasm that new accessories, such as image tubes, may permit important use to be made of older refracting telescopes, among them the world's largest, the 40-inch at Yerkes, which was erected in 1897. Because of its long focal length in proportion to its aperture, this instrument has never been pushed to its photographic limit — no matter how long an exposure is used the sky background cannot be reached. Dr. Morgan said that, with some spectral-region limitations, image intensification might bring the 40-inch within less than an order of magnitude of equaling the work of the great reflectors.

Another dedication speaker, Alan T. Waterman, director of the National Science Foundation, recalled that as early as 1951 Indiana University astronomer John B. Irwin had reported on the optimum location for a photoelectric observatory. Based on his analysis of the number of "photoelectric" nights — entire nights without a trace of cloud — he found "the desert peaks in southeastern California and southwestern Arizona near Yuma are probably almost a

Attending the dedication were astronomers, observatory directors, scientists from many fields, businessmen, government officials, and a major general.



This scale drawing of the 36-inch reflector shows it pointing directly northward along the polar axis. The main counterweight arm, balancing the telescope tube and accessories, fits close to the main-pier housing. Within the latter are a number of preload weights that pull constantly against the right-ascension and declination driving mechanisms to eliminate play and backlash, operating through a system of cables and pulleys. The observing floor can be raised and lowered seven feet, permitting comfortable observing whether the telescope points toward the zenith or close to the horizon. The main tube will usually be operated on the east side of the polar axis, as seen in the front cover, so there will be no need to switch it over to the other side when passing the meridian during an observing period. As this diagram shows, the declination drive is located in a rectangular housing, which is conspicuous in the cover view. A second 36-inch reflector, now at Steward Observatory in Tucson, will eventually be set up on Kitt Peak.

factor of two better for photoelectric research than other large existing American observatory sites."

A conference on photoelectric techniques supported by the NSF was held at Flagstaff, Arizona, in 1953, when University of Michigan astronomer Leo Goldberg suggested the establishment of an interuniversity observing center for all branches of astronomy. The foundation appointed a special advisory panel for a national astronomical observatory, headed by Robert R. McMath, under whose direction the plans went forward apace. A. B. Meinel was executive secretary of the site selection committee, and later director of the observatory. The Association of Universities for Research in Astronomy (AURA, Inc.) was formed to establish and operate the observatory under a contract and grants from NSF,

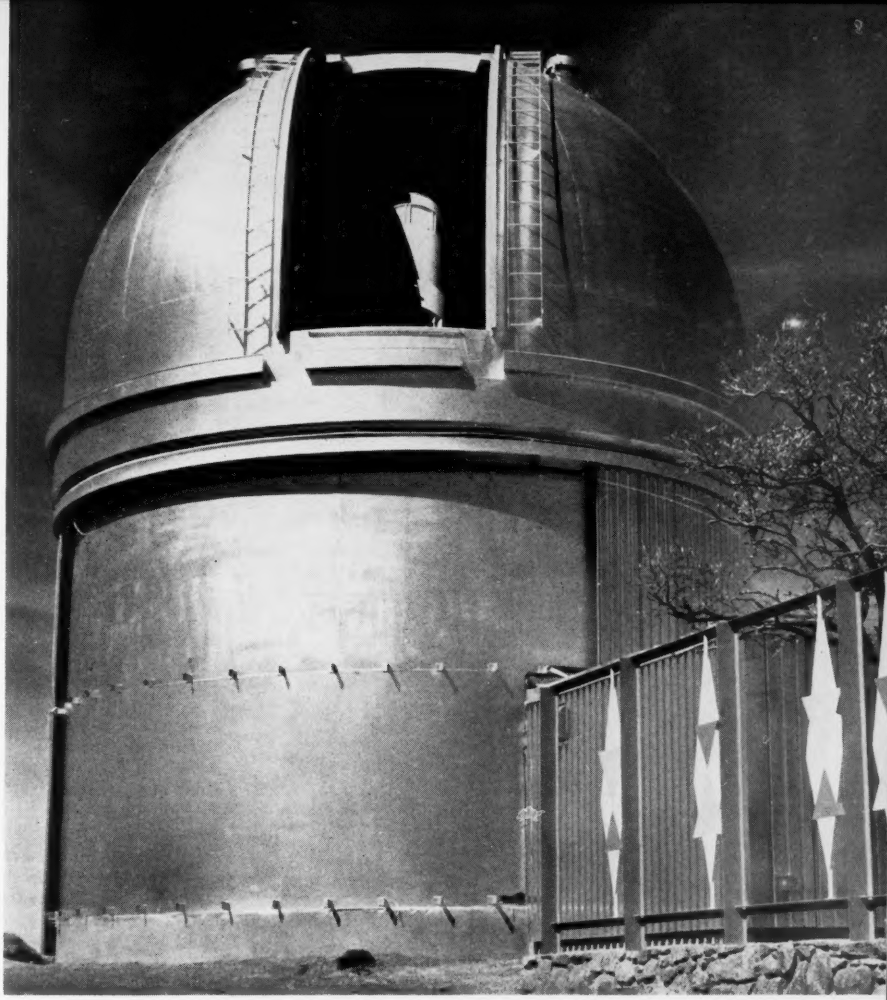
the participating institutions now being California, Chicago, Harvard, Indiana, Michigan, Ohio State, Princeton, Wisconsin, and Yale.

The first large research instrument on Kitt Peak is the 36-inch Cassegrainian reflector, with an effective focal length of 40.5 feet. It is equipped with a ratio spectrometer, which compares the amount of light in wide and narrow regions of a star's spectrum (see SKY AND TELESCOPE for November, 1959, page 18). The 36-inch telescope also can carry such photoelectric devices as that pictured here. This three-color Strömgren photometer is being tested by D. Crawford to ascertain the suitability of its design for Kitt Peak instruments.

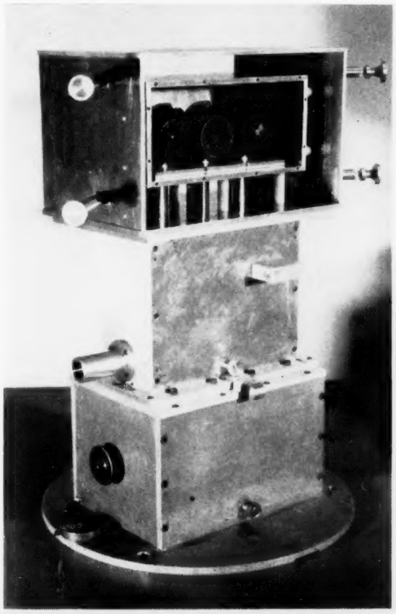
The 84-inch reflector when finished will also be used primarily for photoelectric and spectroscopic purposes. At its Cassegrainian focus the focal length will be 53.3 feet, and the coude focal length, 200 feet. The spectrograph cameras will yield spectra from a few millimeters to several meters long. Compactness and ease of operation will speed up observations with the 84-inch. The mirror for this instrument is now in the optical shop in Tucson, where it will be completely processed, from rough grinding to final testing in the telescope itself on the mountaintop. The 84-inch dome is to be 53 feet in diameter.

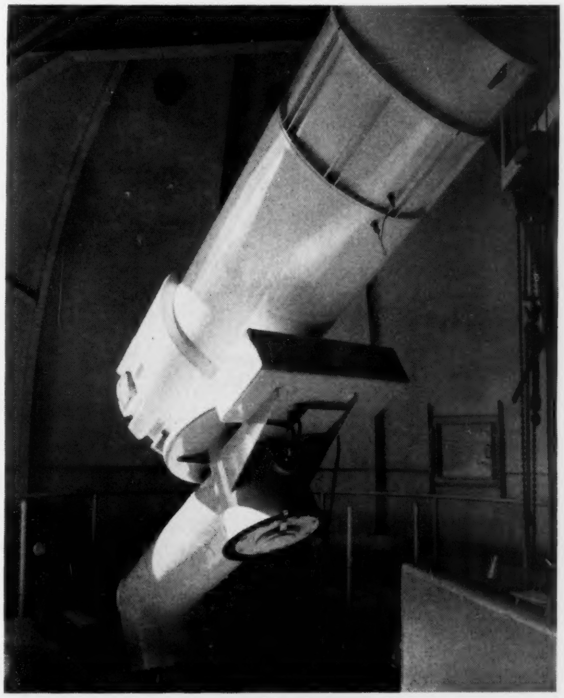
The world's largest solar telescope will one day operate on Kitt Peak, where ground-breaking at its location on the south rim took place the morning of the March dedication. This huge instrument will have a focal length of 300 feet, forming an image of the sun 34 inches in diameter — more brilliantly illuminated than at present possible with any other long-focus solar telescope.

The light collector will be an 80-inch flat mirror, supported 110 feet above the



The upper end of the 36-inch reflector is seen through the slit of its 30-foot dome. Some of the corrugated sheets that form the insulating air pocket around the building have been removed, as they were wind-damaged due to improper installation. National Science Foundation photograph.

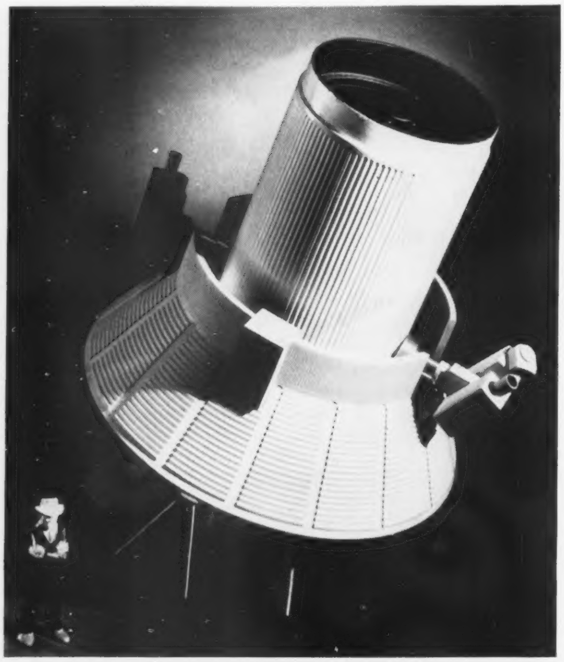




Right: A view of the 36-inch instrument, showing how the main counterweight extends downward beneath the observing floor (in lower left of photograph).

Left: The three-color photometer that may be attached to the 36-inch telescope. The top section is an icebox that contains three 1P21 photomultipliers; the central part carries the optics (three filters, a beam splitter, a dichroic filter, plane mirrors, and Fabry lenses); while the bottom has a large field eyepiece and the mounting plate for attaching to the telescope. Kitt Peak photographs by J. C. Golson.

Forty miles west of Tucson, where the side road to Kitt Peak turns off Arizona highway 86, a trailer community has grown up for the workers on the three-million-dollar access road, which will be completed in about 1½ years. The contractor uses the airplane to travel from one project to another, landing here on the roadway. The route of the new road carries it around three sides of the mountain's 6,875-foot summit ridge. Photograph by Jack Schaeffer.

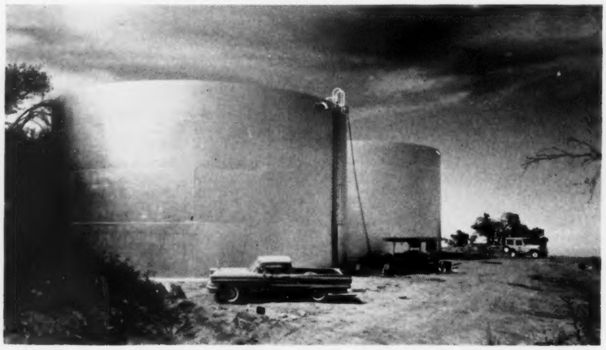


A model of the 50-inch satellite telescope, as it is envisaged at the present time by Aden B. Meinel. This large reflector will have a 24-hour orbit (at 6.6 earth radii), so it can be controlled from a single ground station. The guiding-telescope pairs on either side of the unit will pick up and stay locked upon definite sets of bright stars, thus orienting the telescope in a fixed position with reference to the sky. The weight of the telescope is estimated as 5,000 pounds. The trim flaps (lower left) will be used to control the pressure of solar radiation. Photo by Ray Manley.

ground and mounted as a heliostat. Sunlight striking the flat mirror will be reflected southward along the polar axis to a 60-inch paraboloidal mirror located 480 feet away at the lower end of a diagonal shaft drilled into the mountain. The next reflection is 280 feet long to a 48-inch mirror that will send the light into an underground observing room, where the image may be photographed in whole or part or observed with spectrographs.

Four million dollars in federal funds have been granted to the solar telescope project, which will fulfill a long-felt need of solar astronomers, and which is under the direction of A. Keith Pierce, associate director of Kitt Peak National Observatory. The great size of the optical system creates serious engineering problems in the design and maintenance of the entire instrument, particularly in matters of heat dissipation and temperature control of both the optical components and the extremely long air path of the light beams.

Problems of equal difficulty are being undertaken by Dr. Meinel, who is de-



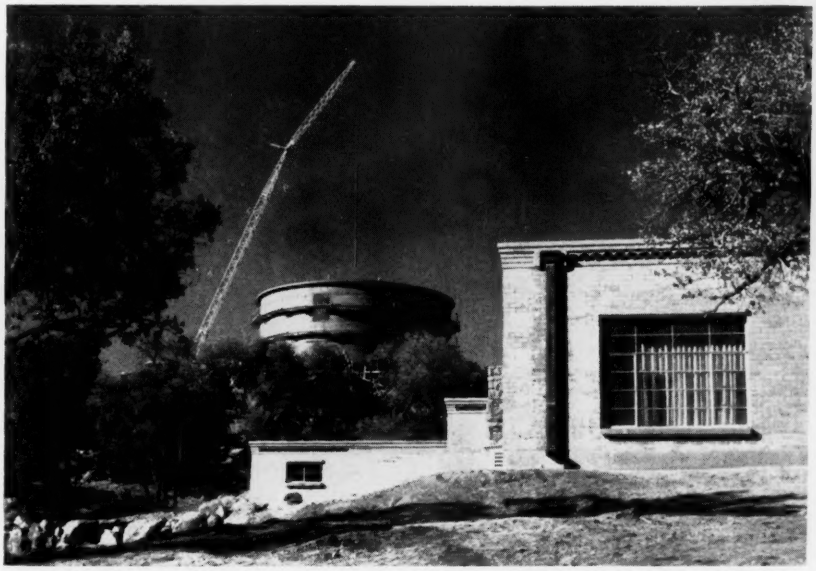
One of the major problems of establishing a permanent observatory on a mountain in a relatively arid region of the country is that of water supply, 1,500,000 gallons being needed in a year. At the left is the two-acre area that has been coated with asphalt to form a huge catch basin for rain water, most of which falls during summer thunderstorms. The water is pumped into the 500,000-gallon storage tanks at the right, the depth on March 15th being about 14 feet out of a total of 28 feet in one tank. Kitt Peak Observatory photographs.

The headquarters in Tucson are modern in design, housing the administrative and research offices, the library, photographic storage vaults, and shop facilities. The optical laboratory is in the windowless section at the right, where the 84-inch mirror blank is being processed. Engraving courtesy AURA, Inc., and University of California Press.

veloping the stellar observing program with instruments both on the ground and high above the earth's surface. He proposes within a decade to place in orbit a 50-inch astronomical reflector, which might send observations back to earth for as long as 10 years. NSF has granted more than $400,000 to the space-telescope program, permitting AURA scientists to start engineering work on a prototype space instrument. They are working in co-operation with the National Aeronautics and Space Administration.

In order to devote himself more fully to this and other aspects of stellar research at Kitt Peak, Dr. Meinel has resigned as director, thereby concluding five years of administrative activity for the national observatory project. He remains on the scientific staff, and the acting director is C. D. Shane, president of the AURA corporation.

These good-natured guests at the dedication were, left to right: B. F. Burke, Carnegie Institution of Washington; Rupert Wildt, Yale University Observatory; Frank K. Edmondson, Goethe Link Observatory and vice-president of AURA, Inc.; and Father Theodore M. Hesburgh, C.S.C., president of the University of Notre Dame. Photograph by Jack Schaeffer.



On the morning of dedication day, construction work proceeded without interruption on the circular wall of the 84-inch telescope building. It is seen past one of the new observatory buildings, of typical southwestern design.

A square block in the city of Tucson, across the street from the Steward Observatory, has been leased by the University of Arizona for the national observatory headquarters. Here, in modern air-conditioned offices, the staff and visiting astronomers will spend most of their time in Tucson, but when observing on the mountain will occupy comfortable dormitory apartments. Driving time to Kitt Peak will be an hour via the new road.

On the mountain there is an office and laboratory building, a shop and maintenance facility, the dormitory, and family dwellings for the small resident staff. A museum for astronomical exhibits is planned, with space for the Papagos to display their baskets and other products of Indian art. The public may inspect the instruments and enjoy the sights and views from the mountain, but visitors are strictly cautioned against disturbing or removing any Indian relics to be found there.

C. A. F.

A field of galaxies in the southern constellation Fornax, photographed with the Baker-Schmidt telescope of the Boyden Observatory in South Africa by B. J. Bok. Whether these patches of light were remote Milky Ways or whether they were small nearby nebulosities was a major issue in the 1920 debate on the distance scale of the universe.

A Historic Debate About the Universe

OTTO STRUVE

*National Radio Astronomy Observatory**

WHEN A. E. Whitford, who is now the director of Lick Observatory, was teaching astronomy at the University of Wisconsin, he used to re-enact each year with his students the historic debate, "The Scale of the Universe," which took place just 40 years ago, on April 26, 1920, at the National Academy of Sciences in Washington, D. C.

The original speakers were two of the most famous astronomers of the present century. Harlow Shapley, then a Mount Wilson staff member, later became director of Harvard Observatory; Heber D. Curtis was at that time director of Allegheny Observatory and later of Michigan. Both astronomers had made extensive investigations of the arrangement of stars and clusters in the Milky Way, Shapley at Mount Wilson and Curtis mostly at Lick, but they had reached strikingly different conclusions.

Their papers, published in the *Bulletin* of the National Research Council (Vol. 2, Part 3, 1921), constitute one of the most exciting accounts in the history of science. Even today, astronomers argue about who was right and who was wrong, and why there was so much disagreement. All the essential questions raised in the debate have been answered in the last 40 years, and only a few of the astronomers who were in the audience are active today. Yet, even among the younger generation of astronomers the Shapley-Curtis controversy is frequently the subject of spirited discussions.

Both participants supported their conclusions with formidable arrays of observational data which they themselves had secured. Both had carefully scrutinized observations by others and checked their results. Both had prepared written statements and had exchanged them in advance of the meeting. Each had made minor revisions after reading the views of his opponent, but neither found it possible to accept the other's principal conclusions.

Two main questions were involved. Is our Milky Way galaxy a relatively small system, with the sun fairly close to the center (Curtis), or a system much larger than hitherto thought, with the sun far from the center (Shapley)? Are the spiral nebulae "island universes," that is, other galaxies (Curtis), or relatively small nearby objects (Shapley)?

Here were two men, equally distinguished, yet with opposite outlooks. Shapley was the daring innovator, pressing the last bit of information from his observations, unafraid to extrapolate from the known to the unknown, and in his reasoning occasionally depending upon intuition to supply connecting links that were not directly available from observed data. Curtis, on the other hand, was a cautious, sometimes overcautious, conservative who weighed every observation and more often concluded "not proven" than "not so."

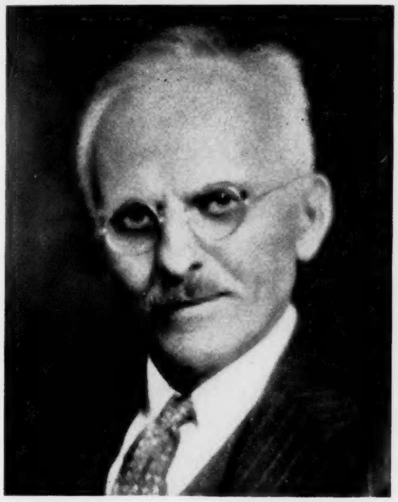
In 1920, Shapley was already well known for his studies of globular clusters. He spoke first in the debate, setting the stage by defending the following chain of propositions:

The great globular cluster M13 in Hercules, he had found, is about 36,000 light-years from us, and he determined distances of some other globulars by the same procedures. Another method was to assume that all globular clusters were equal in linear size, thus giving their distances by comparison of their angular diameters with that of M13. The most remote clusters, Shapley maintained, were several hundred thousand light-years distant.

The system of the globular clusters

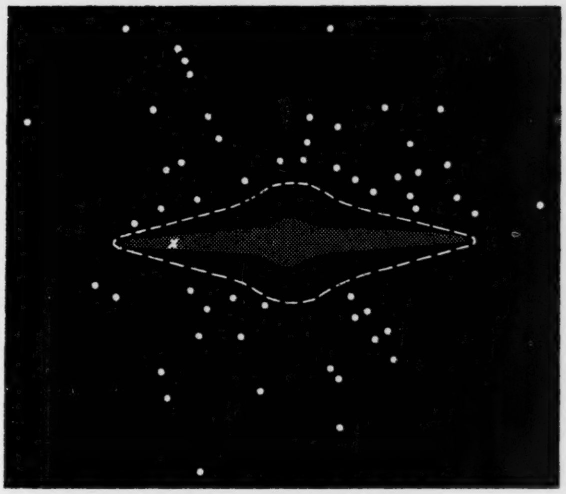
Harlow Shapley was 34 years old at the time of the Washington meeting, where he argued that the Milky Way galaxy was much larger than had been generally believed.

*Operated by the Associated Universities, Inc., under contract with the National Science Foundation.



Left: In the 1920 debate, Heber D. Curtis advocated essentially the present-day view that the spiral nebulae are other Milky Ways, at great distances from our own stellar system.

Right: Globular clusters, shown by dots, form a spherical halo around the main body of our galaxy, where the sun's location is marked by a cross. Shapley's demonstration of this model was a very important advance for 20th-century astronomy.



forms the skeleton of our Milky Way, Shapley continued, and is symmetrical around a point defined by him as the center of the galaxy, located in the constellation Sagittarius about 50,000 light-years from the sun. The diameter of the Milky Way, as defined by the system of globular clusters, was found to be on the order of 300,000 light-years.

Next the Mount Wilson astronomer considered the status of the spirals. If they were stellar systems resembling the Milky Way in size and structure, they would have to be at enormous distances, roughly 10,000,000 light-years in the case of the nearby great Andromeda nebula, M31. But this, he maintained, raised a serious inconsistency; the ordinary novae that had been observed in the Andromeda nebula would have to be much more luminous than the ordinary novae of the Milky Way. This consideration would rule out what he called the "comparable-galaxy" theory of spiral nebulae.

To refute still further the island-universe hypothesis, Shapley drew upon the observational results of several other astronomers. F. H. Seares had deduced that all of the spiral nebulae had greater surface brightnesses than our galaxy, and J. H. Reynolds had studied the distribution of light and color in typical spirals, concluding they could not be stellar systems. Finally, A. van Maanen had measured what he believed to be the rotation of M33 in Triangulum, corroborating his earlier work on M101 and M81. This indicated that these bright spirals could not reasonably be the excessively distant objects required by the island-universe hypothesis.

Although Shapley devoted little of his talk to the problem of the spirals, he described them as probably nearby objects that do not belong to our galaxy but are scattered more or less uniformly in space. The Milky Way, in its motion through intergalactic space, travels among the spirals, only the nearest of which are bright enough to be seen. In doing so, our galaxy exerts a peculiar repelling force upon the spirals, causing them to move away from the central plane of the Milky Way. In this way, Shapley sought to account for both the zone of avoidance of the spirals (they are practically absent from Milky Way constellations) and for the predominantly recessional velocities observed by V. M. Slipher and others.

During his 1920 debate, Shapley pointed out that Curtis and he were in essential agreement on the following facts. Both regarded Shapley's *relative* distances of the globular clusters as substantially correct. (They assumed that there is no apparent absorption of light in space.) The two astronomers also shared the belief that the stars in clusters and remote parts of the Milky Way are not peculiar, but of the same kinds as those in the sun's neighborhood. The globular clusters are a part of our galaxy, and therefore the size of the Milky Way is probably not less than the size of their array.

Relying on these points of agreement, Shapley based his case upon a defense of his distance of 36,000 light-years for M13. Curtis argued that while the *relative* distances of the globulars were probably correctly estimated by Shapley, the actual distances were all exaggerated by a factor of about 10. Hence for M13 he would have adopted about 3,600 light-years. (Later in the debate he modified this value to 8,000.) To refute this viewpoint, Shapley presented the following table, contrasting some predicted properties of M13 for assumed distances of 36,000 and 3,600 light-years, respectively.

Let us trace these four lines of evidence in turn.

Shapley had found a number of 15th-magnitude blue stars in M13, which he identified with ordinary galactic *B*-type stars. We now know this contention was incorrect. There are very few blue stars in globular clusters, and those that may be assigned to spectral classes *A* and *B* are certainly not normal, young *A* and *B* stars such as are found in the neighborhood of the sun. They are, according to our present view, old stars that have exhausted their internal supply of hydrogen, and have reached spectral type *B* after passing through the giant and supergiant stages of their evolution. These old *B* stars do have absolute magnitudes of about zero and, therefore, seemingly support Shapley's argument of 1920. But they are certainly not a demonstration of the "uniformity of conditions and of stellar phenomena naturally prevailing throughout the galactic system," a postulate Shapley had adopted at the outset.

Shapley's second point concerned the absolute magnitudes of the brightest member stars in the cluster. He correctly argued that, because of the great distances of the clusters, yellow and red dwarfs could not be observed, only the more luminous giants and supergiants. Such stars in the Milky Way have absolute magnitudes of the order of −1.

At Mount Wilson, W. S. Adams and Shapley had taken low-dispersion spectrograms of some of the brightest stars in M13, and it seemed reasonable that they

Property	*36,000 light-years*	*3,600 light-years, or less*
1. Mean absolute photographic magnitude of blue stars*	0	+5, or fainter
2. Maximum absolute photographic magnitude of cluster stars	−1.0 to −2.0	+3.2, or fainter
3. Median absolute photovisual magnitude of long-period Cepheids	−2	+3, or fainter
4. Hypothetical annual proper motion of cluster	0".004	0".04, or more

*Of negative color index.

were similar to yellow and red giants and supergiants in the sun's neighborhood. If the distance of the cluster were 36,000 light-years, its brightest members would have absolute magnitudes matching their nearby counterparts, but if the distance were 3,600 the absolute magnitudes would be around +3. There was no doubt then, nor is there now, that in this respect Shapley's argument stood the test.

The third criterion for the distance of M13 involves the period-luminosity relation of Cepheid variable stars. Curtis had severely criticized this relation, pointing out that many Milky Way variables not used in Shapley's calibration of the relation failed to agree with his curve. Shapley correctly explained that the shape of the curve was known from Miss H. Leavitt's study of the Magellanic Clouds, and that the only important quantity obtained from the Milky Way Cepheids was the average absolute magnitude for the entire group.

In 1920, it was impossible to determine reliable distances of individual Cepheids, and in that way compile the period-luminosity curve, but the mean absolute magnitude could be found fairly precisely. At that time, there could be no serious doubt that the known Cepheids and RR Lyrae stars were very luminous objects, with absolute magnitudes ranging between zero and about −4. An average of −2 for Cepheids agreed with a distance of 36,000 light-years, and disagreed with Curtis' 3,600, because in the latter case the average absolute magnitude would come out +3 or fainter.

The last line of argument concerned the motions of clusters. Shapley pointed out that the line-of-sight velocities of the globulars, as measured from their spectra, were about 150 kilometers per second. It was reasonable to assume that the average velocity at right angles to the line of sight would be the same. On this basis, the brighter globular clusters should have proper motions of around 0.04 second of arc per year, if they were only 3,600 light-years distant. But a large body of observations had shown the proper motions of the clusters were much smaller than this; hence, their distances must be much greater than 3,600 light-years.

As we know now, Shapley had overestimated the distance of M13 by about 50 per cent. The latest determination, as reported by Helen S. Hogg in 1959, is approximately 25,000 light-years. His figures for the more remote clusters, the distance of the sun from the galactic center, and the over-all diameter of the Milky Way are too large by a factor of about three. The true distance of the center is around 30,000 light-years, and the diameter of our galaxy is now listed as 80,000 or 100,000 light-years.

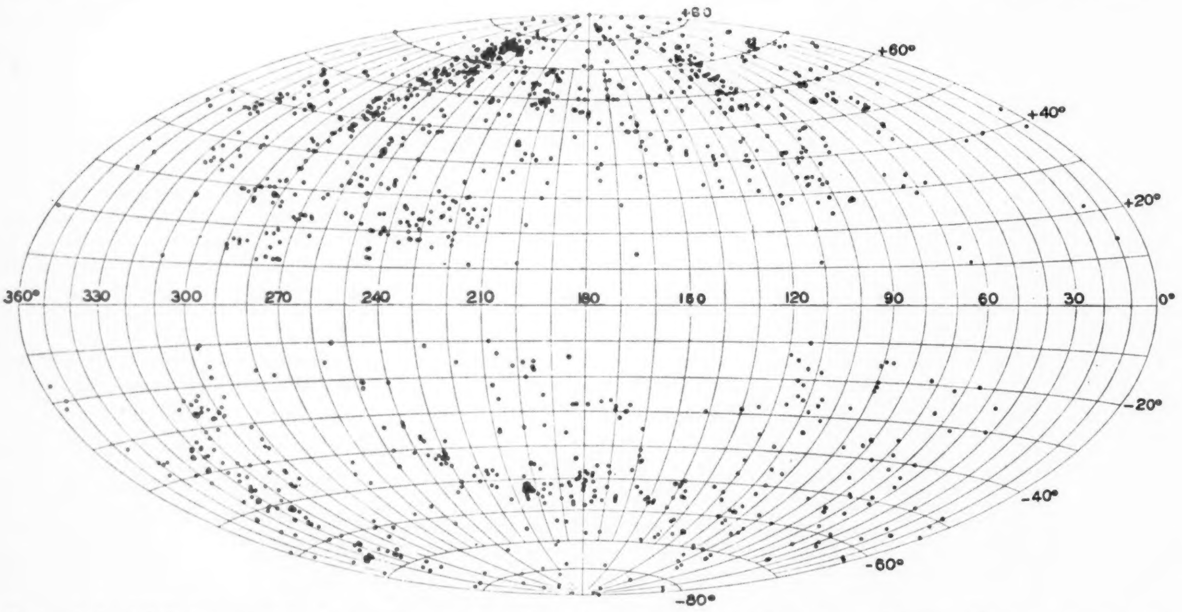
Part of these discrepancies come from the fact that the criteria used by Shapley were only first approximations. But the principal source of error lay in his being unaware in 1920 of the importance of interstellar absorption of starlight by cosmic dust. He must have relied heavily upon the earlier conclusions by H. Seeliger, J. Kapteyn, and others, who had strongly advocated the idea that interstellar space was essentially transparent. Looking back upon the history of astronomy during the past 100 years, it is difficult to understand how so many astronomers in the 1920's could have ignored interstellar absorption, a phenomenon that had been clearly demonstrated in 1847. It should have aroused the interest of all who looked at the photographs of the Milky Way by E. E. Barnard, Max Wolf, and others.

Turning now to Curtis' paper, we find that his criticism of Shapley's distance of M13 was based in part on the incorrect assumption that the yellow and red stars in globular clusters must be dwarfs, resembling the sun in absolute magnitude. This might have been correct if it could have been shown that the globulars were devoid of giants and supergiants, but it ignored the fact that the spectra of the brightest stars indicated high luminosity.

Curtis felt strong misgivings about the reliability of distances obtained by means of Cepheid variables. In his opinion, ". . . available observational data lend little support to the fact of a period-luminosity relation among galactic Cepheids." He summarized his conclusions about the distance of the great Hercules globular cluster: "There are so many assumptions and uncertainties involved that I am most hesitant in attempting to assign a given distance to a given cluster, a hesitancy which is not diminished by a consideration of the following estimates of the distance of M13. . . .

Shapley, 1915, provisional	100,000 light-years
Charlier, 1916	170 light-years
Shapley, 1917	36,000 light-years
Schouten, 1918	4,300 light-years
Lundmark, 1920	21,700 light-years

"It should be stated here that Shapley's earlier estimate was merely a provisional assumption for computational illustration, but all are based on modern material, and illustrate the fact that good evidence



Each of the 1,249 dots on this chart represents a bright galaxy from the Shapley-Ames catalogue. There are practically no galaxies along the central line of the Milky Way (the horizontal axis of this diagram), although they are abundant elsewhere. The interpretation of this zone of avoidance was a question on which Curtis and Shapley strongly disagreed in 1920. The former correctly attributed it to obscuring matter in space. Harvard Observatory diagram.

Like many other spiral nebulae that are turned edgewise to our view, the galaxy NGC 891 in Andromeda shows a strong dark lane of obscuring matter. If our Milky Way system was similar in nature, the zone of avoidance could be simply explained, Heber D. Curtis pointed out in the 1920 debate. Mount Wilson and Palomar Observatories photograph.

may frequently be interpreted in different ways.

"My own estimate, based on the general considerations outlined earlier in this paper, would be about 8,000 light-years, and it would appear to me, at present, that this estimate is perhaps within fifty per cent of the truth."

There can be no doubt, except for the disregard by both speakers of the effects of interstellar absorption, that Shapley was more nearly correct in the determination of the distances of the globular clusters than was Curtis. But Curtis was not primarily concerned with the clusters. His principal interest pertained to the spirals, and the latter part of his paper is an admirable defense of the island-universe hypothesis.

He reminded the audience that Shapley had in previous papers advocated distances of the order of 20,000 light-years for nearby spirals with angular diameters of one or two degrees. But the smallest clearly discernible spirals were five seconds of arc across, or less. Assuming again "the general principle of approximate equality of size for celestial objects of the same class," the smallest spirals would therefore be about 1,000 times farther than the nearest ones, which Shapley had placed at 20,000 light-years. Hence, apparently small spirals would be 20,000,000 light-years distant, or far outside the boundaries of the Milky Way postulated by Shapley.

Even more convincing was Curtis' insistence that the known spectra of the spirals were indistinguishable from those of great aggregations of *F*- and *G*-type stars, and in no way resembled the spectra of gas clouds. Hence he disagreed with Shapley's viewpoint that the spirals "are truly nebulous objects," or that "spiral nebulae . . . are, however, members of the galactic organization," and "the novae in spirals may be considered as the engulfing of a star by the rapidly moving nebulosity."

Moreover, Curtis correctly explained why so few spiral nebulae are observed in the galactic plane. Pointing out that many edgewise spirals showed peripheral belts of dark occulting matter, he suggested that our own Milky Way system possessed the same feature, which would obliterate from view the distant spirals, thus causing the zone of avoidance. On Shapley's hypothesis, as we have seen, an unknown physical force would be required to repel all spirals away from the central plane of our Milky Way.

Novae in the Andromeda nebula provided Curtis with another powerful argument. On his hypothesis, that spiral was about 500,000 light-years distant. (We now know it to be approximately three times that far.) Hence the novae in M31 should have an average absolute magnitude at maximum of −4, in good agreement with the −3 determined from four galactic novae of known distance. But if the Andromeda nebula were only 20,000 light-years away, the novae in it would be of absolute magnitude +3, making them objects of an entirely different nature from the ones in our Milky Way.

Perhaps the most imaginative portion of Curtis' discussion was in connection with the motions of the spirals. Here he faced the consequences of the large measured radial velocities of the spirals, which implied large transverse velocities. Closely related to this were van Maanen's observations of the rotations of several spirals, at that time accepted by most astronomers. Van Maanen's photographs at Mount Wilson showed sizable transverse motions of condensations in spirals. But the resulting rotation periods were so short, cosmically speaking, as to imply improbably rapid motions, unless the spirals were nearby objects. Curtis' comments in 1920 were so prophetic that they should be read by every astronomer:

"*Proper motions of the spirals.* — Should the results of the next quarter-century show *close agreement among different observers* to the effect that the annual motions of translation or rotation of the spirals equal or exceed 0″.01 in average value, it would seem that the island universe theory must be definitely abandoned.

"A motion of 700 km/sec across our line of sight will produce the following annual proper motions:

Distance in light-years	Annual proper motion
1,000	″.48
10,000	″.048
100,000	″.005
1,000,000	″.0005

"The older visual observations of the spirals have so large a probable error as to be useless for the determination of proper motions, if small; the available time interval for photographic determinations is less than twenty-five years.

"The first proper motion given above should inevitably have been detected by either visual or photographic methods, from which it seems clear that the spirals can not be relatively close to us at the poles of our flattened galactic disk. In view of the hazy character of the condensations measured, I consider the trustworthy determination of the second proper motion given above impossible by present methods without a much longer time interval than is at present available; for the third and the fourth, we should need centuries."

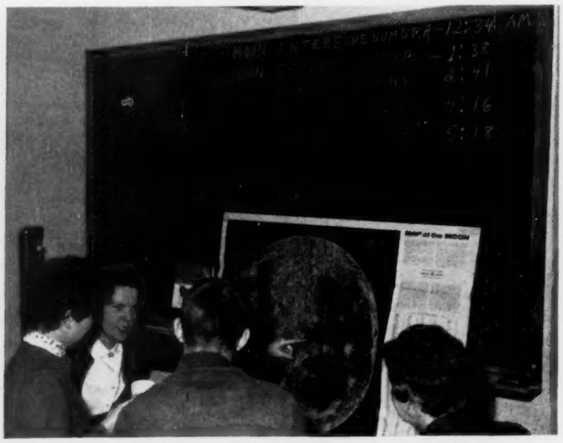
This appraisal has fully met the test of time. The final words in regard to the controversy about the rotation of spirals were printed in two papers in the *Astrophysical Journal* for 1935, by E. Hubble and van Maanen. These made it clear that the rotations measured on photographs were observational errors.

To summarize the historic debate, I believe it correct to state that our present picture of the universe's structure is a blend of the ideas of Shapley and Curtis. Shapley had correctly concluded that our solar system is located far from the center of our galaxy, and that the latter is considerably larger than previously believed. Curtis was correct in advocating that the spirals are other Milky Ways, comparable with our own galaxy.

The entrance of the moon into the earth's shadow at the March 13th total lunar eclipse was photographed by Ed Strittmatter at Tucson, Arizona. The image formed by his 6-inch reflector was projected through a low-power eyepiece and recorded by an Exa camera on Tri-X film. He took the four pictures above at 6:31, 6:41, 6:51, and 7:01 Universal time, respectively, each exposure being 1/150 second long. This series, which is Mr. Strittmatter's first attempt at photographing the moon, is continued on the facing page.

Amateur Photographs of the March Lunar Eclipse

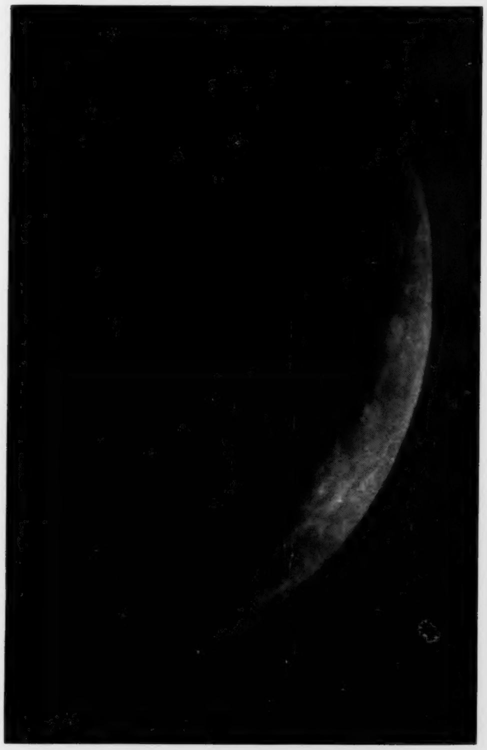
From hundreds of pictures submitted to Sky and Telescope *by amateurs in nearly all parts of the country, these have been selected as representative of successful photography with a variety of equipment. For a roundup of eclipse reports, a summary of the various kinds of observing programs, and a list of correspondents, see page 418 of this issue.*



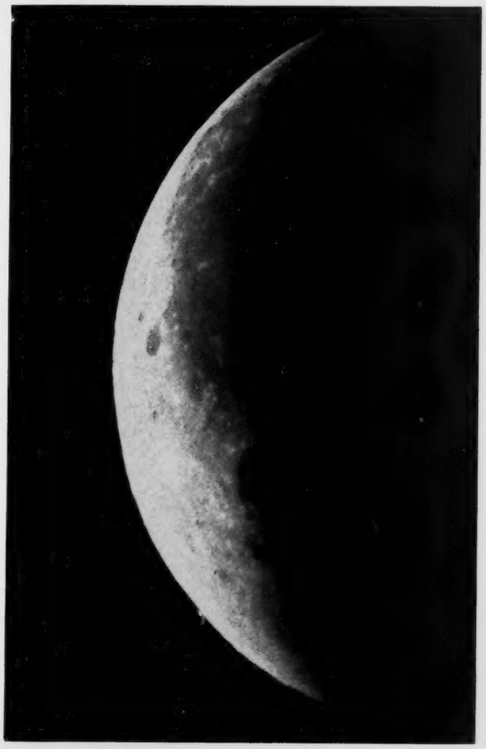
Above: Many amateur societies set up elaborate plans for observing the eclipse. Here members of the Forsyth Astronomical Society in Winston-Salem, North Carolina, are being briefed on what to look for by Mrs. Min Eidson. The blackboard shows the time schedule of the phenomenon. Photograph by H. G. Eidson, Jr.

Left: Claude S. Dean's two-hour exposure with a stationary camera shows the brightness change of the moon during totality and as it emerged. The break midway in the picture was caused by a flagpole, which is barely discernible. Working at Narberth, Pennsylvania, Mr. Dean used a miniature Graflex camera at f/11 and Kodak Super-XX film.

Mr. Strittmatter's series is continued from the facing page, to show the onset of totality. Again the images are at 10-minute intervals, beginning at 7:11, the exposures being 1/50, 1/50, 1/25, and 1 second, respectively.



Left: Most of the moon had entered into the earth's shadow when F. N. Lewis, Royal Oak, Michigan, made this 1/25-second exposure with his 8-inch reflector at 7:27 UT. As with all other pictures in this article, the moon is shown uninverted, north at the top.



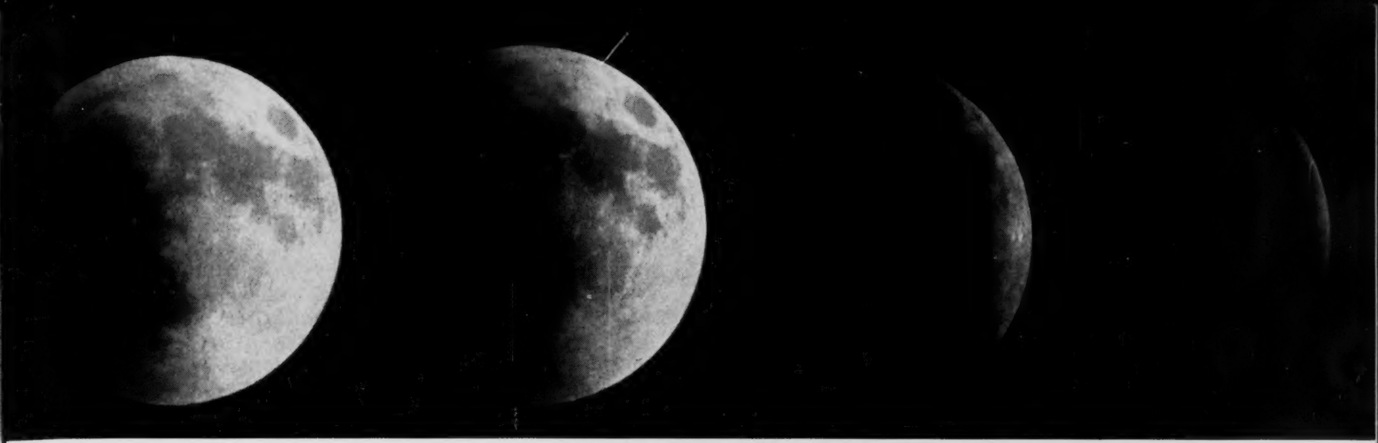
Right: At 9:30 UT, somewhat after totality ended, the eastern part of the moon was emerging as Leo Deming obtained this record with his 8-inch reflector at Terre Haute, Indiana. This is a $\frac{1}{5}$-second prime-focus exposure on Panatomic-X film. The large dark crater at left center is Grimaldi; Aristarchus is the bright crater that has just come out from shadow, in the top part of the picture.

Right: While many observers reported unfavorable weather conditions for the March eclipse, members of the Forsyth Astronomical Society had clear skies. There were seven inches of snow on the ground. The amateurs watched the event with six telescopes, and used a dozen cameras. Photograph by H. G. Eidson, Jr.

Above: Three stages in the eclipse are shown from the series of 17 photographs taken by Dan Judd, as part of the observing program of the Albuquerque Astronomers in New Mexico. The top view, at 5:40 UT, indicates the penumbral darkening of the northeast edge of the moon. The second, taken at 6:20 UT, 18 minutes before umbral eclipse began, shows the penumbra strongly. At the bottom, 7:00 UT, the umbral eclipse is well advanced. Mr. Judd used fast Ektachrome film at the prime focus of his 10-inch f/7 reflector. With information gained from this event, the society plans to make a double series of pictures during the forthcoming September 5th total eclipse of the moon.

Above: Clear skies at St. Paul, Minnesota, allowed Bruce Brenden and Douglas Backman to record the moon every four minutes as it was moving out from the earth's shadow. The moon's diurnal motion spaced successive images one degree apart. The two Macalester College students used an f/6 Aero Ektar lens of 24-inch focus. During the eclipse, S. W. Schultz, Jr., of the Macalester astronomy department, secured about 4,000 exposures with an 8-inch Springfield reflecting telescope.

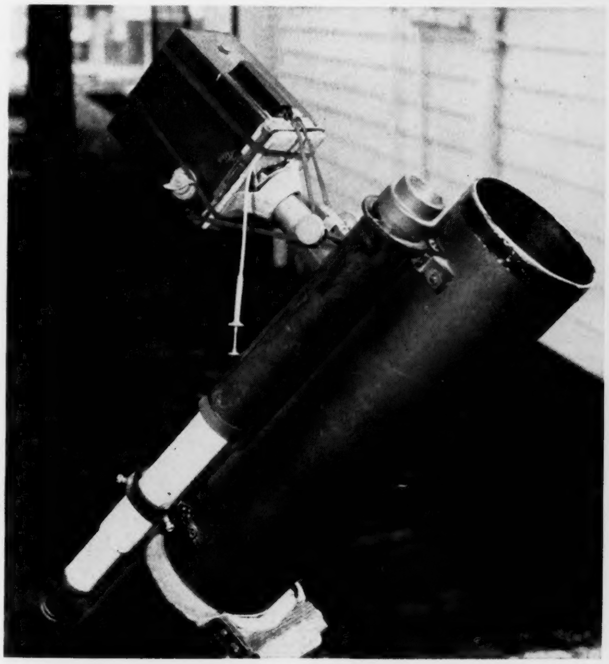
Left: Some of the more than 30 Macalester astronomy students who took part in the night-long observing program for the March 13th eclipse. In the foreground, a girl is using one of four compact telescopes to photograph the phenomenon, while another coed in the left background watches it through a $3\frac{1}{2}$-inch refractor.

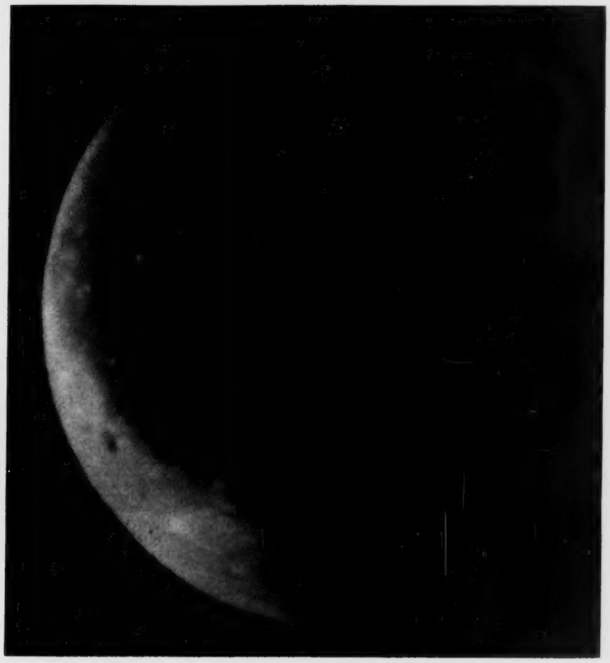


Above: Despite clouds at Chicago, Illinois, F. M. Klicar secured these four photographs of the opening stages of the eclipse with his 6-inch f/5 reflector. From left to right, they show the event at 6:43, 6:53, 7:23, and 7:36 UT, respectively.

Right: Twelve of M. H. Meyerhoff's pictures with a 2.5-inch f/8 refractor were combined by him to illustrate both the entrance of the moon into the earth's shadow and its exit. He observed at Glen Burnie, Maryland, with other members of the Chesapeake Astronomical Society.

Below: William P. Searcy, New Orleans, Louisiana, used this simple arrangement for mounting a modified box camera on his 4-inch reflector to obtain the picture shown at the right. The one-second exposure was made as the moon was leaving the earth's shadow, at 9:38 UT.





A Radio Astronomy Study of the Earth's Atmosphere

JULES AARONS, *Air Force Cambridge Research Center*

TO the average astronomer, the problems of the bending of light waves in the lower atmosphere, obscuration by clouds, and the dancing of a stellar image are likely to provoke far more annoyance than interest. Radio astronomy also is confronted with the effects of refraction, absorption, and scintillation, and in certain respects these are more complex than their optical counterparts.

As with classical optical astronomy, radio refraction necessitates an altitude correction for low-angle viewing, but refraction by the ionosphere, extending from 60 to 400 kilometers above the earth's surface, must be considered as well as that in the lower atmosphere. Absorption of radio waves is one of the principal deterrents to the extensive use of wave lengths of eight millimeters and shorter, even though this region holds much fascination for the radio astronomer. The third effect, scintillation or twinkling, has been the subject of many radio experiments, and it is much more complicated than its optical cousin.

In the early days of radio astronomy, soon after World War II, fluctuations in energy from certain radio stars were noted. The first interpretation was that the source's radiation changed with time, just as the sun's does. Later data obtained in England, at Cambridge and Manchester, showed that the sources were stable in output, the variations in intensity being produced somewhere between each source and the receiver. At meter wave lengths — the low frequencies — these fluctuations showed a direct relationship to the ionospheric layers.

The effects of optical refraction and absorption near the horizon, where the light must traverse the greatest extent of the earth's atmosphere, can be seen in this multiple exposure of the sun rising at Ipswich, Massachusetts. The lifting of the sun's image by refraction is shown by the stronger curvature of its apparent path near the horizon. All illustrations with this article courtesy Air Force Cambridge Research Center.

A group of French scientists, working on microwave scintillation data, made a further discovery. At the Ecole Normale in Paris, with a 3-centimeter system, J. L. Steinberg noted scintillations as the sun was rising. He ascribed this phenomenon to lower-atmosphere disturbances, suggesting that the number of electrons in the ionosphere was too small to affect such microwaves — the high frequencies — to any great extent.

The Air Force Cambridge Research Center's radio astronomy section has been investigating the effects of the upper and lower atmosphere on radio energy from discrete sources and from the sun, with emphasis on refraction, absorption, and scintillation. Studies at 218, 1,300, 3,000, and 4,700 megacycles, as well as at 3.2 centimeters (9,375 megacycles) and 8.7 millimeters (32,900 megacycles), have been made with a variety of already available equipment.

The antennas have ranged in size from an 18-inch one for microwave work to a sea interferometer at 218 megacycles, and now include the 84-foot paraboloid at Sagamore Hill, Hamilton, Massachusetts. The receiving equipment includes total-power receivers at 100 and 400 megacycles, a switching radiometer at 218, microwave radiometers, and a group of traveling-wave tube radiometers at 1,300, 3,000, and 4,700 megacycles. The latter were developed by the AFCRC Electronics Research Directorate, and are some of the most basic pieces of equipment we have used.

In 1955 the first traveling-wave tube radiometer was tested, but it was immediately placed in a restricted category. Declassification occurred in 1957, and the radiometer was put into operation by the radio astronomy section. The system has also been employed in two commercial receivers.

The concept involved is relatively simple. The ability of a receiver used in radio astronomy to detect small signals is proportional to the square root of the product of the band-width and the time constant, as shown by the formula on page 28 of SKY AND TELESCOPE for November, 1959. Therefore, the use of hundreds of megacycles of band-width has a great advantage over the 5- to 10-mc. spread normally employed.

With the first radiometer, operated at 4,700 megacycles, an 800-mc. band-width was used. Our newly developed units at 1,300 and 3,000 utilize 200-mc. band-widths. Of course, some new problems have arisen, especially radar interference. Our solution is to limit observation times

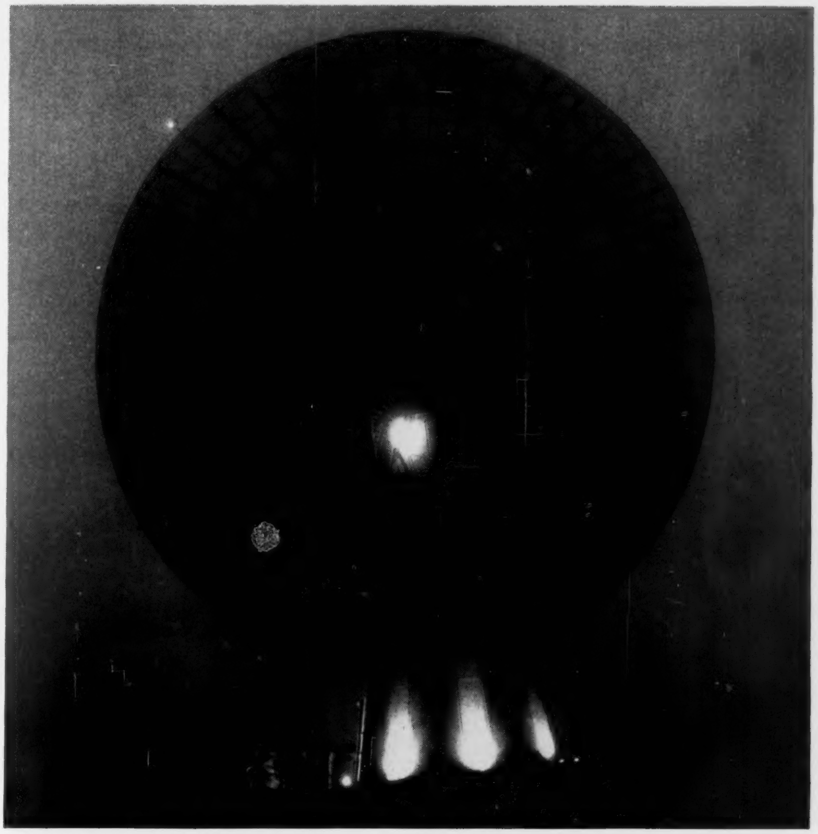
and to cut down on band-width for certain programs that do not require extremely high sensitivity.

Another valuable device is the sea interferometer, introduced by Australian scientists. This resembles closely the Lloyd's mirror in optics, and has been used successfully by our radio astronomy section. A radar antenna, called "Billboard" because of its similarity to large roadside signs, was designed for defense purposes and operated at 218 megacycles. For radio astronomy, this unit could track in azimuth for sunrise measurements during the spring and summer months. It was located at Fourth Cliff in Scituate, Massachusetts, directly overlooking the ocean at a height of 77 feet above mean sea level.

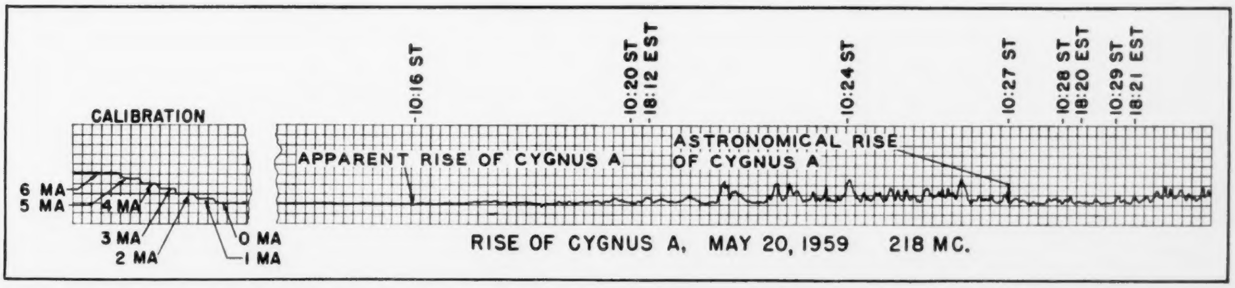
Perhaps our most comprehensive study has concerned amplitude fluctuations of radiation from the quiet sun, Cygnus A, and Cassiopeia A. In the microwave region the tropospheric effects, produced from ground level to 40,000 feet, show fluctuation periods on the order of several seconds to over a minute. The chart on page 408 illustrates the types of variation recorded when the sun was allowed to drift across the antenna pattern of our 4,700-mc. radiometer near sunrise. At this frequency, rhythmic fluctuations fell to less than one per cent when the antenna elevation was greater than 10 degrees.

Earlier measurements of microwave emission from the sun showed scintillations clearly distinguishable from solar bursts. Many of the characteristics of optical twinkling are evident. The period of scintillation frequently shortens as the altitude increases. Intervals of a minute or longer between maxima predominate in the first few degrees of the sun's altitude, while short-period scintillations (to a few seconds) occur at higher elevations. In addition, the scintillation amplitude decreases with increasing elevation of the source. According to radio astronomers of the Meudon Observatory, such scintillations are produced by winds at the height of the tropopause, about 12 kilometers.

When the data are obtained at frequencies lower than those in the microwave region, an entirely different section of

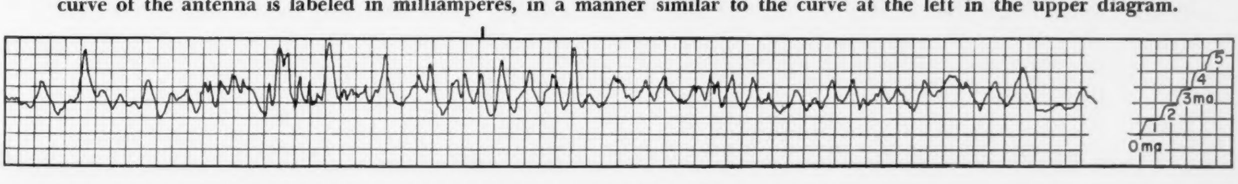


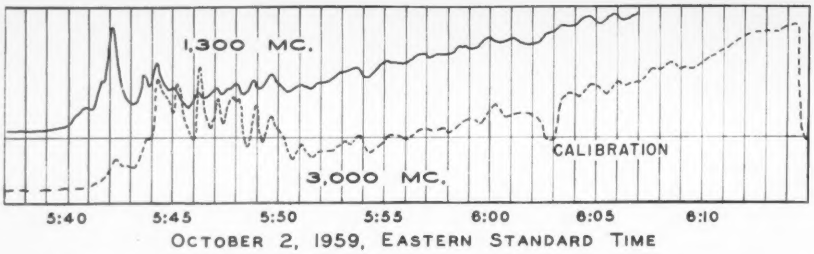
On the morning of October 2, 1959, the 84-foot antenna at Sagamore Hill, Massachusetts, was lowered to the direction at which the eclipsed sun was to rise. Since this point was below the horizon-limit-switch level on the antenna, once a warning signal came on, all further movements of the giant dish were made with the aid of a man signaling with a flashlight.



Above: As a measure of the radio refraction at the horizon, the apparent rise of Cygnus A at 10:16 sidereal time is compared with its optical rising 11 minutes later. Radio refraction corrections can be as large as 1½ degrees (compared to optical corrections of up to 34 minutes of arc), and are due to effects of both the troposphere and the ionosphere.

Below: A drift curve for Cygnus A, when it was only three degrees above the western horizon on August 3, 1959, shows the large scintillations produced by the atmosphere. The time axis is horizontal, each box representing 11 seconds, and the tick mark at the top of the grid (left of center) marks 13:57 Eastern standard time. At the right, the calibration curve of the antenna is labeled in milliamperes, in a manner similar to the curve at the left in the upper diagram.





These records of the October 2, 1959, eclipse were made with the 84-foot dish (solid curve) and an 8-foot antenna (dashed curve). The large fluctuations at 1,300 megacycles occurred when the sun rose with its east limb still uneclipsed, showing some of the most intense effects of this kind ever recorded. Even during totality, which began at 5:50 a.m. EST, the scintillations continued. Notice the close correlation between the peaks and troughs of the curves for the two frequencies.

the atmosphere enters the picture — the ionosphere. Studies at Ohio State University have shown that the influence of various ionospheric layers extends to frequencies as high as 1,000 megacycles.

The disturbed ionosphere can cause some of the discrete sources to scintillate even at the zenith. Our 84-foot dish at 218 megacycles has recorded variations amounting to 10 per cent of the total signal at an altitude of 70 degrees.

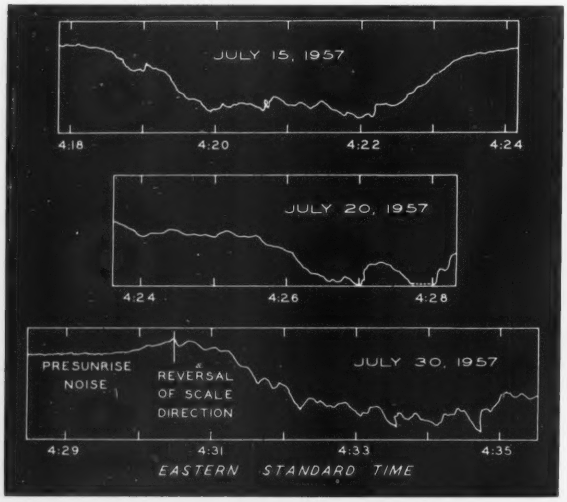
For ionospheric scintillation, the change of period with altitude is more complex than in the tropospheric case. The records show the deep fades and high amplitudes of scintillations during the rise of Cygnus A at 218 megacycles. Refraction is measured by comparing the astronomical time of rising to the observed time, both of which are indicated in the record.

During auroral displays, the rapidity of the scintillations increased by a factor of two or more. Charts on page 407 are of normal scintillations at 218 megacycles with predominant periods of 15 seconds. The depth of the fades does not change significantly at times of an aurora.

A comparison of observations shows that the scintillations vary among the sources. Cygnus A and Cassiopeia A are both small, with angular diameters of 2.3 and 3.8 minutes, respectively, but at very low angles scintillations of Cygnus A are more marked than those of Cassiopeia A. However, the sun as a whole, when viewed with the sea interferometer and the 84-foot antenna, does not show scintillations, though small fluctuations were detectable from plage areas. At 218 megacycles, the sun's apparent diameter is 45 minutes of arc, about half again its optical size.

The total eclipse of October 2, 1959, was observed from the Sagamore Hill site, which was in the path of totality. The low altitude of the sun (approximately one degree), combined with point sources on its surface, gave large scintillations at 1,300 and 3,000 megacycles, but failed to show them at 224. No point sources are evident at this last frequency, but have been noted at 1,420 and 3,300 megacycles on interferometric maps of the sun by W. N. Christiansen and R. N. Bracewell. Thus the point sources produced very large scintillations during the sunrise eclipse.

Individual peaks and nulls were extremely well correlated at the two frequencies observed with separate antennas. The 1,300-mc. equipment was on the 84-foot paraboloid, while the 3,000-mc. radiometer was combined with an 8-foot antenna 80 feet from the large one.



Different types of intensity fluctuation observed when the sun drifted across the 4,700-mc. radiometer's antenna pattern near the horizon. The small scintillations at the top are six per cent of the antenna temperature, while the large long-period scintillations in the center (July 20, 1957) are 19 per cent of antenna temperature. At the bottom, presunrise noise is followed by drift-curve scintillations about 15 per cent of antenna temperature.

Tracings of the data obtained during the eclipse illustrate the correlation mentioned above. The scale of irregularities is large in the lower atmosphere where homogeneous areas produce changes in refraction. Our observations show that the tropospheric scintillations are not frequency-sensitive in the range from 1,300 to 3,000 megacycles.

In general, we find that small sources scintillate while larger ones do not. However, the angular sizes of the sources that show this effect in the optical and radio cases are radically different.

There are many problems still to be worked out in this field. Among these are the separation of ionospheric and tropospheric contributions. Moreover, we would like to estimate the size and altitude of the homogeneous regions mentioned above.

QUESTIONS... FROM THE S+T MAILBAG

Q. How can I find the cardinal points of the compass from the stars?

A. The north point of the horizon is directly beneath the average position of the North Star, Polaris, at the end of the Little Dipper's handle. The east point is where a star on the celestial equator, such as Delta Orionis (top star in Orion's belt), rises, and the west point is where it sets. South is directly opposite to the north point.

Q. Is it possible to see the zodiacal light from the northern United States?

A. Yes, the zodiacal light is sometimes easily seen after sunset in the spring by mid-northern observers (and before sunrise in the autumn). Wait until the twilight arch in the west has diminished to about 10 degrees high, then look upward along the ecliptic constellations for a wedge-shaped glow of diffuse light.

Q. What is meant by seconds and minutes of arc?

A. They are subdivisions of the familiar angular measure of which the principal unit is a degree, a right angle having 90° and a full circle 360°. There are 60 minutes (60′) in a degree, and 60 seconds (60″) in a minute. The moon has a diameter of approximately half a degree, so a minute of arc is about 1/30 the moon's angular diameter.

Q. What type of film should I use for photographing the moon at the Newtonian focus of my reflector?

A. A rather slow, fine-grained film is best for this purpose. Kodak Microfile and Panatomic-X are quite suitable. Good results can also be had from Ektachrome or Anscochrome color films, which yield a positive picture and will record the faint lunar hues.

W. E. S.

OBSERVING THE SATELLITES

Pioneer V

FOR the first time, direct observations of conditions in interplanetary space are being made many million miles from Earth. This achievement resulted from the launching of Pioneer V on March 11, 1960, into a solar orbit that lies between the paths of Venus and the earth. Two earlier space probes, one American (Pioneer IV), the other Russian (Lunik III), have been sent into orbits slightly larger than the earth's, but all radio contact with them was lost at about 400,000 miles. Pioneer V's improved communications system has allowed it both to receive commands and to telemeter signals to the earth at unprecedented distances.

The firing was from Cape Canaveral, Florida, at 13:00:07 Universal time on March 11th, after a series of postponements extending over many months. This operation was conducted for the National Aeronautics and Space Administration by Space Technology Laboratories, Inc., under the supervision of the U. S. Air Force ballistic missile division.

A Thor-Able IV rocket configuration served as the vehicle. During the first 160 seconds after launching, the modified Thor IRBM booster, weighing over 50 tons, developed about 165,000 pounds of thrust. This unit contained an autopilot, which controlled roll and pitch according to a precalculated flight plan, and initiated the separation of the burnt-out first stage from the upper sections.

Immediately after this separation, the 4,000-pound modified Able second-stage rocket fired, and continued to burn for about 100 seconds, developing around 7,500 pounds of thrust. This stage, too, had its self-contained guidance system, but there was also provision for steering on command from the ground. This control was not used, however, since the vehicle followed the desired trajectory.

The ground-based automatic command system did, however, serve to shut down the Able engine within 0.1 second of the prearranged moment. Immediately thereafter, a radio signal ordered the jettisoning of the plastic nose fairing that had protected the payload as it rose through the dense lower atmosphere. Next, six small spin rockets, arranged around the skin of the burnt-out second stage, were ignited to set it rotating 120 times a minute.

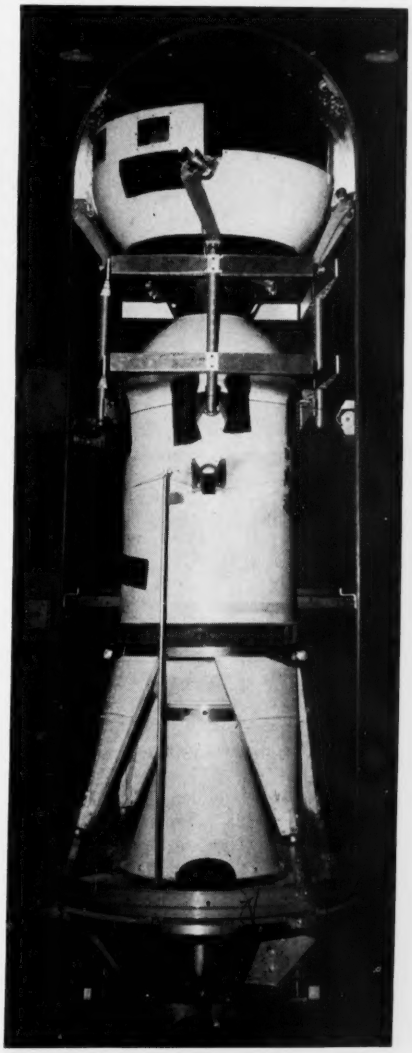
This served two purposes: it stabilized the yet unfired third stage, and caused the four paddles hinged down on the probe to swing out into position. The 500-pound third-stage solid-propellant engine operated for about 40 seconds, delivering a thrust of approximately 3,000 pounds.

More than 20 minutes elapsed before the probe was separated from the third stage, at 13:27 UT. This was effected by a Space Technology Laboratories scientist located in a trailer at Jodrell Bank, in England, who sent a signal that caused the fusing of a hold-down bolt, thereby permitting springs to divide Pioneer V from its burnt-out carrier. Presumably the separation was delayed this long to aid radar tracking, the combined components affording a better radar target for the large antennas in the tracking network. In deep space, however, a still-attached third stage would interfere with radio transmissions from the probe, and would block some sunlight from the silicon cells that power the probe's instruments.

The orbital velocity of the empty 50-pound rocket casing is very close to that of the 94.8-pound Pioneer. Hence they are evidently following nearly identical orbits around the sun, although only the probe can be tracked, by its radio signals.

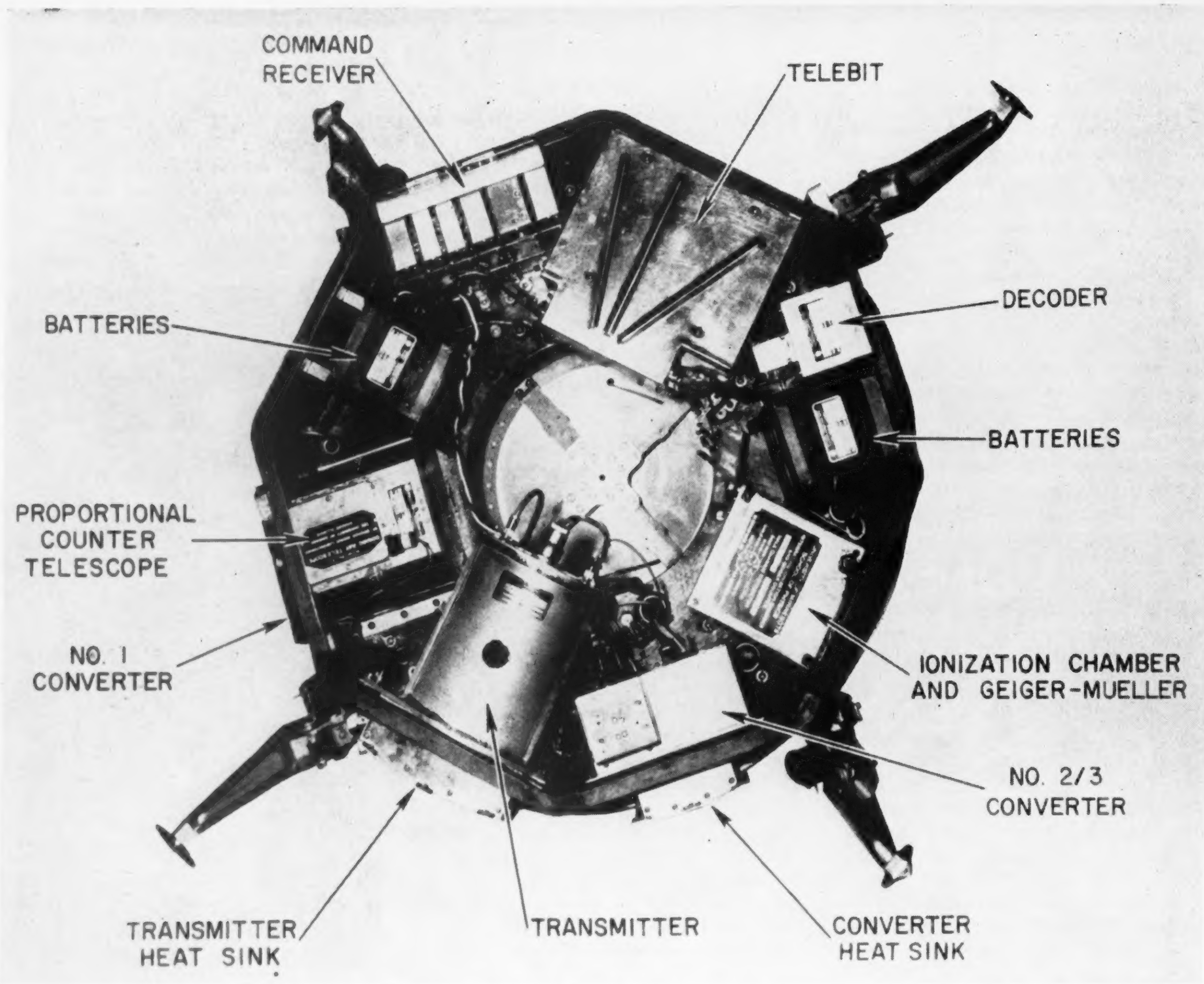
Compared with Explorer VI, the earlier paddle-wheel satellite now moving in a highly elongated orbit around the earth, Pioneer V had to be given a considerably greater velocity, in order to travel far enough from Earth for solar gravitation to predominate over terrestrial. As a result, the new probe had to be much lighter than Explorer VI's 142 pounds, and carried fewer experiments and fewer silicon solar cells.

When fully extended from the 26-inch



Right: The third stage of Pioneer V is assembled and ready for final testing. On top of it sits the space probe itself, hooded by half of its fiberglass protective shroud. (See also the picture on page 411.)

Left: Ernest Baines checks one of the wires that feed power from the solar-cell paddles to batteries within the shell of Pioneer V. The paddle in the foreground is one of four, and carries 600 light-sensitive cells on each side. Both pictures from Space Technology Laboratories.



A top view of the platform that bisects the body of Pioneer V, showing its electronic equipment. On the platform's other side are a magnetometer, micrometeorite detector, and a sun-sensing device. Note the four projecting paddle brackets. National Aeronautics and Space Administration photograph.

aluminum sphere, Pioneer V's paddles have a wingspread of about $4\frac{1}{2}$ feet. Each of the 14-by-18-inch vanes carries 600 silicon semiconductor cells for the conversion of solar radiation into electrical energy. The photograph on page 409 shows white-painted strips between the rows of cells. The purpose of the paint pattern is to stabilize the temperature at about 0° centigrade, allowing the cells to operate at a rated efficiency of approximately eight per cent. The solar energy cells charge hermetically sealed nickel-cadmium batteries, which feed the converters that provide current to the instruments.

Telemetry showed that two of the paddle arms were successfully locked into their extended positions. For the other two arms no telemetry was arranged, but their proper placement is indicated by the slightly better-than-expected charging rate of the batteries. In the case of Explorer VI, however, one vane did not lock into place, thereby contributing to the failure of that vehicle's radio signals after about two weeks.

Power supply and radio transmitter make up about 50 pounds of the Pioneer's payload. Another 10 pounds are needed for structural parts, including a reinforced plastic flooring across the waist of the sphere, to which is attached the experimental equipment forming the rest of the payload.

A primary purpose of Pioneer V is the measurement of high-energy cosmic rays. For this is used a coincidence counter, consisting of a lead-shielded package of six argon-filled cylinders arranged around a seventh. The total radiation flux is being determined by a gas-filled ion chamber for studying particle energies, and by a Geiger tube for determining their density in space.

Together these experiments may give a valuable insight into the origin of cosmic rays. Since the space probe is expected to encounter drifting clouds of ions, a search-coil magnetometer is carried to measure magnetic fields, which will assist in interpreting the cosmic ray data. In order to determine the orientation of these magnetic fields, the probe carries a small photocell intended as a sun sensor. According to late reports, however, this unit is the only part of Pioneer V's equipment that is not furnishing information. Possibly it is in working order, but unable to see the sun until the orientation of the spin axis with respect to the sun has changed sufficiently.

In a further experiment, a sensitive microphone serves to detect the impact of small meteoritic particles, and indicates their momentum relative to the probe.

Auxiliary devices include thermistors to monitor the temperature of various parts of the probe. Its interior is found in this way to be about 25° C. The outside is painted in a pattern chosen to maintain an even temperature, by suitably balancing the absorption and radiation of heat. In addition, heat sinks of lithium metal are used to remove heat generated by such units as the voltage converters and the radio transmitter. A highly miniaturized "telebit" memory device stores instrument data in digital form during the intervals between telemetering.

The chief novelty in Pioneer V is its

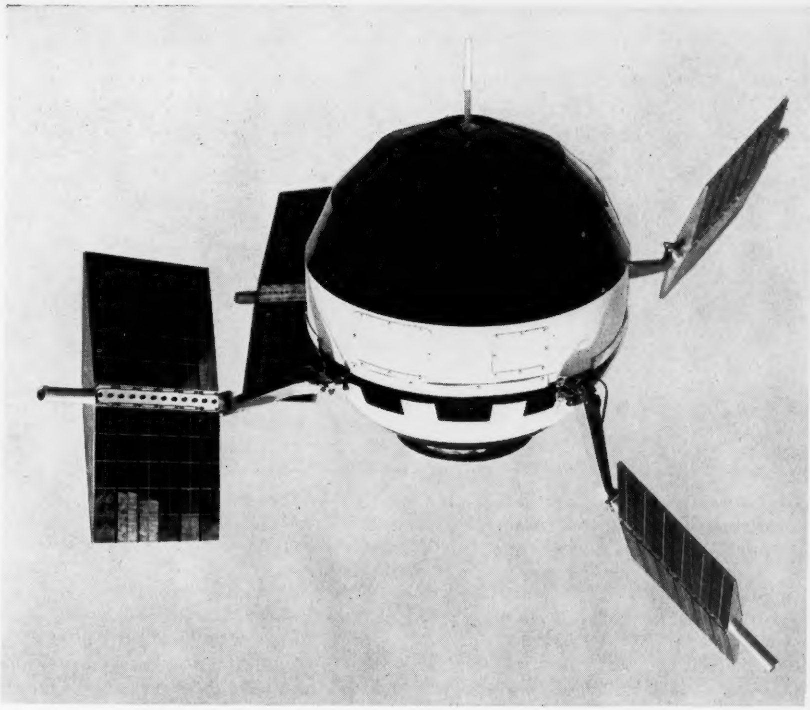
high-power communications system. There is a continuously operating command receiver, which can initiate some 10 different digitally coded functions; it is also the input receiver for tracking purposes.

The transmitter works at an ultrahigh frequency of 378.21 megacycles, with a power output of five watts. It is monitored by primary tracking stations at Jodrell Bank, England; South Point, Hawaii; the Atlantic Missile Range near Cape Canaveral, Florida; Singapore, Malaya; and Millstone Hill, Massachusetts.

As Pioneer V recedes farther from the earth, the signal strength will fade. When the signals are no longer readable, a 150-watt transmitter at the same frequency will be switched in, on command. The five-watt stage will then become the driver for the higher-powered unit, and the antenna is to be switched appropriately. It is expected that the solar cells will suffice to operate the 150-watt transmitter about two per cent of the time. These intermittent signals should be detectable from as far away as 50 million miles.

Sometime late this summer, Pioneer V will reach this distance from the earth. Since the electronic components selected for the transmitter have a "mean time to failure" of at least 2,000 hours continuous operation, there is hope that transmissions may be received in 1963, when the planetoid again reaches the vicinity of the earth.

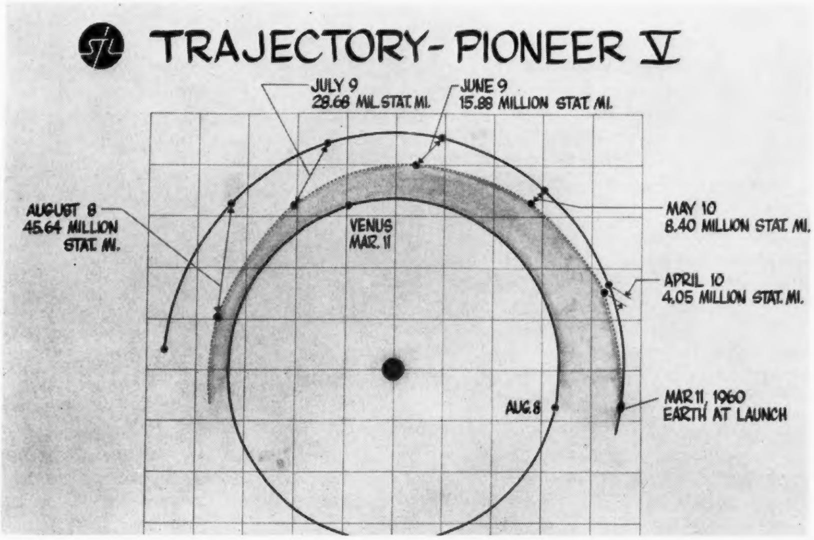
Pioneer V offers the possibility of an important astronomical application — a precise determination of the scale of distances in the solar system. In principle, the length of one astronomical unit can be established from an exact measurement of the distance between the earth and any object moving around the sun in a known orbit. This has been done by radar observations of the planet Venus, in which the two-way travel time of pulses was measured (Sky and Telescope, May, 1959, page 384).



Pioneer V, seen here with its four vanes fully extended, is in orbit between the earth and Venus. The rectangular paint pattern around the center is part of the scheme for maintaining the desired temperature within the probe, to insure efficient operation of the batteries and other electronic equipment. National Aeronautics and Space Administration photograph.

The problem is somewhat different for Pioneer V, whose orbit around the sun is not known in advance with high precision. The time interval will be noted between the transmittal of a signal to the probe's radio and reception of the returned signal. Another type of information is also needed. The frequency of the Pioneer's transmissions, as received at the earth, will shift because of the relative line-of-sight velocity of planetoid and Earth. This radial velocity should be measurable with an accuracy of about three meters per second.

Hence, from a combination of the two kinds of observations, distance and radial velocity, it is hoped to derive both the orbit and the astronomical unit's value.



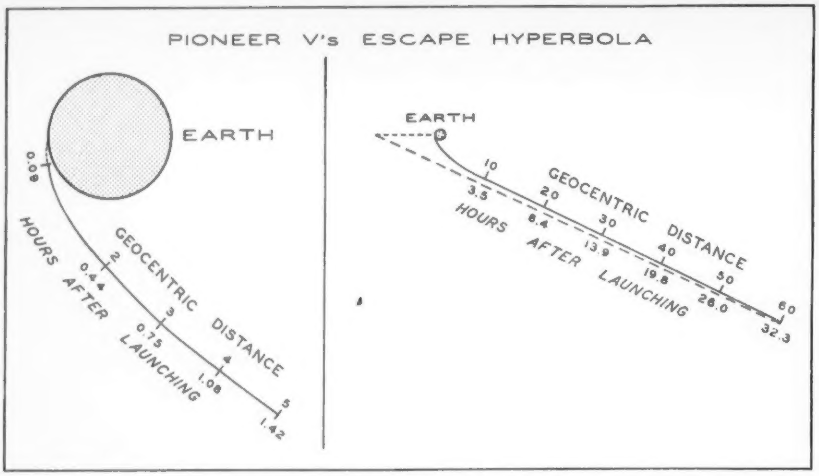
The counterclockwise motions around the sun of Pioneer V (dotted line), the earth (outer curve), and Venus. Each square is 20,000,000 miles on a side. When near the orbit of Venus on August 8, 1960, the probe and that planet will be on opposite sides of the sun. Space Technology Laboratories chart.

The Motion of Pioneer V

In planning the trajectory of Pioneer V, it was originally hoped that it would pass close to or intersect the orbit of Venus. This space vehicle was to become a satellite of the sun, with an elliptical orbit that would have its perihelion at Venus' distance from the sun and its aphelion at the earth's distance. The Space Technology Laboratories diagram shows that the actual orbit does not pass closer than about seven million miles to Venus' path.

Three successive phases in the motion of Pioneer V should be distinguished. The first was powered flight, during which the vehicle was accelerated to a speed greater than the velocity of escape. In the second, the planetoid moved along a hyperbolic orbit relative to the earth, which was at the focus of the hyperbola. Finally, as the probe receded far from the earth's attraction, it became an independent planet of the sun, in the elliptical orbit pictured here.

While Pioneer V did not fully attain



Two diagrams show the hyperbolic path Pioneer V followed in receding from the earth. Geocentric distances are in multiples of the perigee distance (4,064 miles). The dotted arc was covered in powered flight, ending in 0.093 hour.

its intended speed (thus failing to reach Venus' orbit), its 17,687 miles per second at a height of 270 miles above the ground was more than for either of the two previous artificial planetoids. The direction of firing (four degrees north of east) and the time of day were selected so the earth's rotation would help catapult the rocket.

Throughout the three phases of its flight, Pioneer V and the earth maintained normal eastward or direct motion around the sun. But neglecting this and assuming the earth stationary, we can use a relatively simple diagram to show the character of the probe's motion along its escape hyperbola. The plane of the hyperbola is inclined 28°.4 to the earth's equator, the right ascension of the ascending node being 13^h 26^m.

The diagram on this page points out an important characteristic of hyperbolic motion, the asymptote, or straight line in space that the probe gradually approaches as it recedes from the earth. Drawn from the hyperbola's center, which lies at a geocentric distance of 11.41 earth radii, the asymptote extends toward right ascension 5^h 26^m, declination −21°.

By the time Pioneer had reached about a quarter million miles from Earth, the moon's distance, it had already begun to depart appreciably from the hyperbola, as perturbations by the sun became more effective. For the next several million miles, the motion could be accurately calculated only by laborious step-by-step methods, until a region was reached in which the earth's attraction was no longer a predominant factor.

Space Technology Laboratories scientists have computed orbital elements for the third phase of Pioneer's motion, in which it can be regarded as a planetoid moving around the sun.

Pioneer V's orbit is a 311.64-day ellipse whose semimajor axis is 0.89958 astronomical unit and whose eccentricity is 0.10396. The probe will be closest to the sun on August 10, 1960, 12:08 UT, at 0.8061 unit; the aphelion distance is 0.9931. The orbit is inclined 3.351 degrees to the ecliptic, the longitude of the ascending node being 349.712 degrees and the argument of perihelion 357.415 degrees.

Satellite Nomenclature

At a January meeting in Nice, France, a revised terminology for satellites and space probes was recommended by the committee on tracking and telemetry of COSPAR (Committee on Space Research). In this proposal, which is being submitted to the International Astronomical Union, all objects with lifetimes greater than 90 minutes would be given Greek-letter designations, now applied only to artificial satellites. The change would not affect names prior to 1960, but Pioneer V would become 1960α, a terminology already adopted by the Smithsonian Astrophysical Observatory and by the National Space Surveillance Control Center (Space Track).

MARSHALL MELIN
Research Station for Satellite Observation
P. O. Box 4, Cambridge 38, Mass.

APRIL COVER PICTURE NOT AN AURORA?

(Continued from page 391)

being tilted somewhat above the horizontal. Our records for the night of February 27th are as yet very incomplete, but a series of observations from both Portage in Manitoba and Saskatoon in Saskatchewan indicate no auroral activity at all during the first part of the night, and only a very small amount far to the north in the latter half of the night."

Amateur astronomer Harry W. Brauneis, Denver, Colorado, also wrote:

"I think that Mr. Cruikshank saw and photographed light reflected from ice crystals in the air. I believe the night was very cold on February 27th. The hazy sky would have been due to ice crystals in the air and the shopping center furnished the light. I have seen such an event before and I, too, mistook it for an aurora."

Upon receiving copies of the first two communications, Mr. Cruikshank investigated the matter further, and on April 2nd wrote to the editor:

"At 10:00 p.m. the Des Moines municipal airport, where the Weather Bureau office is located, recorded a temperature of 13° Fahrenheit. The weather map shows a snow area to the southwest of the city. I have just talked with the Weather Bureau, and at that time very light snow flurries were recorded but no ice crystals were present in the air.

"My home is about eight miles north and three miles west of the airport, and it was not snowing at the time of my observation. Immediately after the photographs were taken at 10:07 I drove to a darker part of town — due north and only 10 blocks away. From this location I could still see the shopping center but with an unobstructed horizon and no nearby street lights.

"As my original letter (and my observing-book notes) mentioned, the sky 'was not perfectly clear. Only the brightest stars in the east were visible through the hazy sky. Soon, other (but much fainter) rays, parallel to the first, were seen in the east. Also, a faint, broad band extended from the west-northwest horizon to a point well over the zenith. The sky was clear in the west.'

"Upon returning to my home about 15 minutes after the photographs, the rays could not be seen from the exact location of the camera. By this time the sky had become completely cloudy and no stars could be seen.

"There were no searchlights in the shopping center at the time of my observation. The shopping center uses a large number of mercury vapor lights, but they are distributed regularly over a very large (probably 30-acre) parking lot. I did not check the rays with the usual auroral filter combinations. I certainly do not doubt the possibility that I could have overlooked floating ice crystals, but the report of the Weather Bureau at that time suggests that they were not present. The wind velocity was six miles per hour from the northwest, which may have been great enough to dissipate any regular formations of crystals.

"I had made many previous observations of aurorae for the IGY project, and because the February 27th bands had the appearance of auroral streamers I concluded that such was the case. Nevertheless, the Gartlein and Millman interpretations of the photograph are quite reasonable."

Amateur Astronomers

THIS MONTH'S PROGRAMS

Cleveland, Ohio: Cleveland Astronomical Society, 8 p.m., Warner and Swasey Observatory. May 20, Dr. C. Schalén, University of Lund, Sweden, "The Structure of the Galaxy."

Dayton, Ohio: Miami Valley Astronomical Society, 8 p.m., Museum of Natural History. May 13, Dr. L. V. Robinson, Wright-Patterson Air Force Base, "Mechanics of the Solar System."

Long Beach, Calif.: Excelsior Telescope Club, 8 p.m., home of Alika Herring, 1312 Arlington Ave., Anaheim. May 6, Alika Herring, "Amateur Observations of the Moon."

New York, N. Y.: Amateur Astronomers Association, 8 p.m., American Museum of Natural History. May 18, motion picture, Research into Controlled Fusion.

Washington, D. C.: National Capital Astronomers, 8:15 p.m., Commerce Department auditorium. May 7, Dr. John Strong, Johns Hopkins University, "High-Altitude Astrophysical Observations."

AN AMATEUR IN COLOMBIA

Amateur astronomy in Colombia is, as far as I know, almost unknown, and it is very difficult to obtain parts for building telescopes. However, I have made a 3-inch refractor in my spare time.

The objective and three eyepieces were purchased from an American firm, and the tube is painted cardboard. Both the declination and polar axles are of $\frac{3}{4}$-inch steel shafting on bronze bearings. The right-ascension gear is four inches in diameter, driven by a worm gear. Aluminum setting circles are five inches in diameter.

My city is in the middle of the Colombian Andes where coffee is grown. We are about 5,000 feet above sea level, with 10,000-foot mountains close by. Observing is difficult since it is too cloudy most of the time, but there are some nights of exceptionally fine seeing.

DELFIN J. LUGO
Apartado Aereo 573
Armenia, Caldas, Colombia

CLEVELAND, OHIO

The 21 amateurs of the Cuyahoga Astronomy Club meet the third Thursday of each month at the Fairview Park regional branch library at 8 p.m. The society's address is 2074 W. 58th St., Cleveland 2, Ohio.

SILVER SPRING, MARYLAND

Seventy-five amateurs, including 10 juniors, have organized the APL Astronomy Club. The president is Irvin H. Schroader, Applied Physics Laboratory, Johns Hopkins University, 8621 Georgia Ave., Silver Spring, Md.

MT. VERNON, OHIO

Formed last November, the Mt. Vernon Astronomy Club has 12 senior and 20 junior members. The president is Dr. Franklin Miller, of Kenyon College. Interested persons should communicate with Leo V. Waddell, 407 Maplewood Ave., Mt. Vernon, Ohio.

LONG BEACH, CALIFORNIA

During the first week in March, the Excelsior Telescope Club set up an exhibit of telescopes and astronomical equipment at the annual hobby show held in the Long Beach municipal auditorium. Over 18,000 persons attended the event.

Our display included a meteorite collection by Richard Norton; Thomas R. Cave's globe of Mars; and the undersigned's black-lighted model of the solar neighborhood, which was built into a light-tight viewing case for presentation in an illuminated room. The telescopes ranged from Bert Sproul's first attempt in 1937, made of a four-inch stovepipe and 2-by-4's, to a de luxe 10-inch reflector.

ERNEST LORENZ
4758 N. Radnor Ave.
Lakewood, Calif.

Bert Sproul, secretary of Excelsior Telescope Club, and a part of the society's exhibit at the Long Beach, California, hobby show, March 4-7. The 4-inch telescope on Mr. Sproul's left was made by him 23 years ago and has a stovepipe for tubing.

+++ AMATEUR BRIEFS +++

An astronomical link to our 50th state: The Hawaiian Astronomical Society in Honolulu, Hawaii, is now a member of the Western Amateur Astronomers.

Sam Friedman, a junior member of the National Capital Astronomers in Washington, D. C., was one of the 40 finalists in the Westinghouse annual science talent search. His project was a study of the dark markings in Saturn's north equatorial belt.

Happy Birthday! The Sacramento Valley Astronomical Society in California recently celebrated its 15th anniversary; the observing group of New York's Amateur Astronomers Association, its seventh.

The Indiana Astronomical Society's meeting date has been changed to the second Sunday of the month. The group convenes at 2:15 p.m. at the Holcomb Observatory in Indianapolis.

"Jumping Jupiter and Gemini Crickets!" Such tongue-in-cheek commentary between an amateur astronomer and his nonastronomical sleep-loving wife appeared in an Abraham and Straus department store ad (New York *Times*, March 13th) for a personal alarm clock. The store is associated with the Long Island State Park Commission in sponsoring star parties at Jones Beach.

Moving days. The Brashear Memorial Museum at 20th and Sarah Streets will now house the telescope building activities of the Amateur Astronomers Association of Pittsburgh, Pennsylvania. In addition, Dr. N. E. Wagman, director of Allegheny Observatory, has given the society permission to set up an advanced optics workshop at the observatory.

The Grumman Astronomical Society, Bethpage, New York, has distributed to its members a pamphlet that contains a full-size sundial that may be cut out and used.

The Whittier Astronomical Society in California has decided to disband its activities for two years. The reason is that its members are scattered throughout the country, working for advanced degrees at various universities.

All but two of the United States (Alaska and Montana) have active amateur societies, according to the listing beginning on page 351 of the April issue. California has 30 clubs; Ohio, 22; New York, 20; Illinois, 18; and Pennsylvania, 17. An unaffiliated amateur astronomer might investigate the possibility of joining a local society to share his astronomical pleasures.

From *Skyward,* bulletin of the Montreal Centre, Royal Astronomical Society of Canada: "There were 11 lunar occultations scheduled as visible from the Montreal area during the month of March. . . . It was cloudy in Montreal for all 11. No comment."

If your club publishes its own newsletter, please add SKY AND TELESCOPE to your mailing list. H. M. C.

NEWS NOTES

NOVA HERCULIS 1960

On March 7, 1960, Olaf Hassel in Norway found a new 5th-magnitude star near the boundary between Hercules and Aquila, not far west of Zeta Aquilae. The 1950 co-ordinates of the nova are right ascension $18^h\ 55^m\ 02^s$, declination $+13°\ 10'.3$, according to measurements made at the Royal Greenwich Observatory.

This region of the sky had been photographed with a patrol camera at Kurasiki Observatory, Japan, shortly before Hassel's discovery. Subsequent examination of these plates showed that the star still was fainter than magnitude 10 on February 24th and 27th. But by March 4th it had reached photographic magnitude 3.0, and on the following night had faded to 3.5.

World-wide reports indicate a steady decline in visual brightness since March 7th. On the 9th, A. F. Jones in New Zealand estimated the nova as magnitude 5.2; by the 19th it was 5.8 according to A. V. Nielsen in Denmark; German amateurs noted it as 6.2 on March 21st and 22nd. Other estimates by members of the American Association of Variable Star Observers agreed in detail with this trend. The latest available AAVSO observation was 6.8, on March 29th.

With the photoelectric photometer of the 16-inch reflector at Kitt Peak Observatory, D. Crawford obtained a yellow magnitude of 5.49, at 11:00 Universal time on March 12th. Another Kitt Peak astronomer, Helmut A. Abt, was one of the first to obtain a spectrum of the nova, using the 60-inch Mount Wilson reflector for the spectrogram reproduced below.

The scale of the original spectrum negative was 21 angstroms per millimeter. The picture extends from the near ultraviolet (left) to the blue region (right) of the nova spectrum. The reproduction is a negative, emission features appearing dark. The intense feature at the extreme right is the $H\beta$ line; near the middle and almost as strong is $H\gamma$; $H\delta$ is farther to the left and slightly weaker. The broad K line of ionized calcium is 48 millimeters from the left edge, while just to its right is the somewhat stronger H line of calcium, which is blended with $H\epsilon$.

Most of the star's light, as Dr. Abt points out, came from a few broad emission lines of hydrogen, ionized calcium, iron, and titanium. Each emission feature had at least one narrow absorption line at its left (short-wave-length) edge. This absorption was produced in the part of the expanding shell that was in front of the central star and hence moving directly toward us. Thus, one of the absorption components just to the left of the $H\beta$ line indicates an expansion velocity of 1,250 kilometers per second. The same line has a second absorption component, corresponding to an expansion of about 1,800 kilometers per second, seemingly due to a second shell that separated from the star later.

These velocities are characteristic of a fast nova – one that runs comparatively rapidly through its sequence of spectral changes and declines quickly in brightness.

In this spectrogram there are very narrow and sharp absorption lines superimposed on the broad emissions of calcium. They are probably due to calcium in the interstellar medium. Their displacements of 11.2 kilometers per second toward the violet agree well with those of interstellar lines in surrounding stars at roughly the same distance as the nova, which Dr. Abt estimates as around 3,000 light-years.

Other early observations of the spectrum of Nova Herculis were made in France, Sweden, Germany, and England. A number of observers commented on the brightness of the $H\alpha$ emission line, which gave a distinctly red color to the nova as seen in telescopes.

PECULIAR SOUTHERN BINARY

Puzzling results from nine years of study of the 9th-magnitude star HD 16157, in Eridanus, are reported by David S. Evans, of the Royal Cape Observatory, in the current *Monthly Notices* of the Royal Astronomical Society (*119*, 526, 1959).

Attention was first directed to this object by the finding at Cape Observatory that it is only 39 light-years distant. In 1951, radial velocity observations were begun with the 74-inch reflector at Radcliffe Observatory in Pretoria, South Africa. They soon showed that the star is a spectroscopic binary with a period of 1.56 days. The spectrum is that of a late *K*-type dwarf, but with bright lines of hydrogen and ionized calcium. In general, one set of spectrum lines is observed; on only three of 26 spectrograms could faint emission features be detected that might belong to the secondary star.

Photoelectric brightness measurements show that HD 16157 may also be an eclipsing variable. This raises a dilemma: If the two components have masses consistent with the spectroscopic observations, then the orbit must have such a small inclination to the plane of the sky that the stars would be improbably large for eclipses to occur at all. Further difficulties in interpretation arise from radical changes in the form of the light curve from one observing season to the next.

The South African astronomer suggests very tentatively that the binary is enveloped in an extended atmosphere which shares to a greater or lesser extent the motions of the component stars. In this case, they might not form a true eclipsing system, the star disks failing to pass in front of one another.

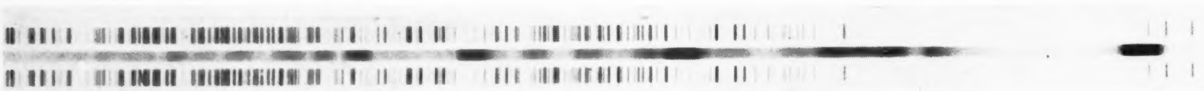
Dr. Evans emphasizes the need for further observations to clarify the nature of HD 16157, and points out the importance such an atmosphere would have in considering the evolution of late-type dwarfs. The closest analogy seems to be the 9th-magnitude companion of Castor, YY Geminorum (SKY AND TELESCOPE, August, 1959, page 552), for which erratic changes of the light curve are far less pronounced than in the present case.

IN THE CURRENT JOURNALS

WHITE DWARFS AND STELLAR EVOLUTION, by Willem J. Luyten, *American Scientist*, March, 1960. "Briefly, what has emerged from this is the picture of white dwarfs as forming a continuous sequence, running from the bluest (and hottest) with luminosities of about one fortieth of that of the sun to the yellowest (and coolest) with a luminosity of about one twenty-five thousandth of that of the sun."

MAGNETOMETER AT WORK IN OUTER SPACE, by Dolan Mansir, *Radio-Electronics*, April, 1960. "The need to have a very accurate absolute measurement of the earth's magnetic field led to the development of the proton magnetometer, and advanced space technology spurred the development of magnetometers for space measurements."

LIFE OUTSIDE THE SOLAR SYSTEM, by Su-Shu Huang, *Scientific American*, April, 1960. "In contrast to the random nature of biological evolution, stellar evolution is governed by the universal law of gravitation and by a relatively small number of thermonuclear reactions."

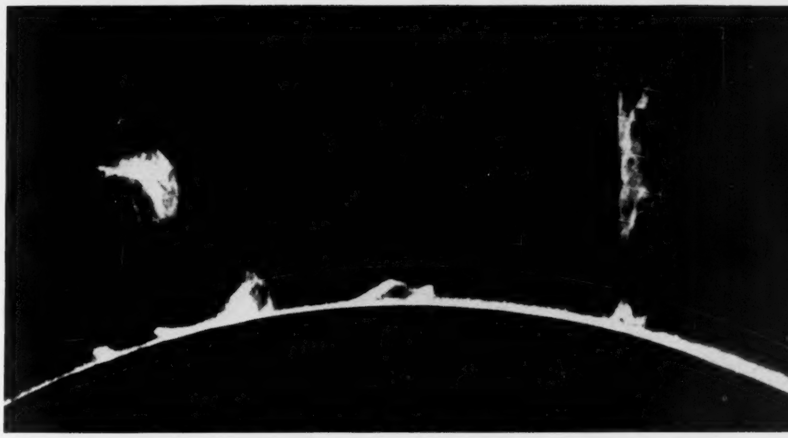


A portion of the spectrum of Nova Herculis 1960, photographed by Helmut A. Abt with the Cassegrain spectrograph of the Mount Wilson 60-inch reflector, on March 8th, at 4 a.m., Pacific standard time. Although he estimated the star's magnitude as 5.0, poor seeing required a one-hour exposure. The nova's spectrum is flanked by comparison spectra of iron, for calibration. See the text for further description. Mount Wilson and Palomar Observatories photograph.

HIGH SOLAR PROMINENCES

Throughout the day of February 13, 1960, the high prominences pictured here were observed at the Popular Observatory, Prague, Czechoslovakia, by Joseph Klepesta. As is typical of many phenomena of this kind, the material seemed to be continually condensing out of the region of the sun's corona, maintaining its general form for hours while beneath it the chromospheric prominences at the sun's edge displayed moderate activity.

To show the scale of the picture, in making the print from his negative Mr. Klepesta superimposed a grid ruled on a piece of plexiglass. The concentric circles are 25,000 kilometers apart, so the top of the cloud at the right is about 175,000 kilometers above the sun's photosphere (visible surface).



Prominences on the sun and high clouds of hydrogen gas, recorded at 13:15 Universal time, February 13, 1960, by Joseph Klepesta.

VISITING PROFESSOR PROGRAM

During the 1960-61 academic year, the American Astronomical Society, under a grant from the National Science Foundation, will continue its program of furnishing visiting professors in astronomy for colleges and universities, especially institutions having little or no astronomy in their curriculums.

In the East and Middle West, address inquiries to Dr. Franklyn M. Branley, American Museum-Hayden Planetarium, New York 24, N. Y.; in the West, Dr. Gibson Reaves, University of Southern California, University Park, Los Angeles 7, Calif.

MOLECULAR SPECTRA

Molecular bands are prominent features in the spectra of stars cooler than the sun, and of comets and planets. But many of the molecules of astrophysical interest are unstable under normal terrestrial conditions; hence laboratory data on their spectral features are incomplete. A more important difficulty, perhaps, has been the great amount of labor hitherto required in the measurement and analysis of these highly complex molecular spectra.

To meet this need, new methods of measuring laboratory spectra and processing the results have been devised by F. A. Jenkins, J. G. Phillips, and their colleagues at the University of California in Berkeley. The first molecule selected was CN, the form in which cyanogen (C_2N_2) is present in comets and cool stars. With a high-dispersion spectrograph, light from this gas was spread out into a spectrum 21 feet long, in which over 20,000 lines were photographed.

The plates were measured with a comparator to which an oscilloscope was attached, permitting the locations of lines to be determined to one part in 10,000,000. As each line was bisected with a movable crosshair, the operator pressed a button, automatically recording both the position and intensity of the line on a punch card. Measurement of the entire 21-foot length of photographs could be done in 15 hours.

These cards were next fed into an IBM 704 computer, which calculated the wave length for each line. Then the machine proceeded to sort out the lines into different spectral series. A large fraction of the total effort in the project has gone into preparing the proper instructions for the electronic computer. This was done by Dr. Phillips, who is an associate professor of astronomy at Leuschner Observatory in Berkeley.

Similar measurements have also been made at Berkeley of the spectra of C_2 (diatomic carbon) and TiO (titanium oxide).

SEASONAL CHANGES IN NIGHT VISION

Researchers in physiological optics have collected much evidence that prolonged exposure of the eye to high light intensities can cause an extended impairment of dark adaptation. For example, one wartime study showed that a few weeks spent in an environment of bright sunlight led to a lowering of night vision that persisted for up to a fortnight. Such facts have a direct importance for the amateur astronomer who makes visual observations of faint objects, whether telescopically or without optical aid.

At the U. S. Naval Medical Research Laboratory, in New London, Connecticut, extensive measurements of night vision have been carried out by Edward J. Sweeney and his associates. In particular, they have found that the sensitivity of the dark-adapted eye shows a conspicuous variation during the year, being greatest from January through May, and least in late summer. They state, "This effect does not depend upon excessive amounts of exposure to sunlight, but is found in individuals going about their normal activities during the seasons."

Details of this investigation were reported by Dr. Sweeney and his coworkers in the March issue of the *Journal* of the Optical Society of America.

NEW LUNAR ATLAS

Publication has just been announced of Gerard P. Kuiper's *Photographic Lunar Atlas,* showing the nearer face of our satellite as recorded by first-quality photographs taken with large telescopes at Mount Wilson, Lick, McDonald, Yerkes, and Pic du Midi observatories. The best of these pictures have a resolution matching that of an 11-inch telescope used visually under ideal conditions. The atlas has been edited by Dr. Kuiper, with the collaboration of D. W. G. Arthur, E. Moore, J. W. Tapscott, and E. A. Whitaker. They chose the best of known photographs.

With a scale of 100 inches to the lunar diameter, 44 fields are needed to cover the visible lunar surface. But since each field is shown under several conditions of solar illumination, there are 281 photographs on the 230 sheets of the atlas, including key charts. Each chart, exclusive of margins, is 16 by 20 inches. Accompanying the set is a 23-page pamphlet of explanation. The entire set, weighing about 20 pounds, comes in a sturdy box, and may be ordered for $30.00 from the University of Chicago Press, 5750 Ellis Ave., Chicago 37, Ill.

HARVARD APPOINTMENTS

Leo Goldberg, director of the Observatories of the University of Michigan, will become Higgins professor of astronomy at Harvard Observatory on July 1, 1960. Also named to the Harvard staff was William Liller, University of Michigan, with the rank of professor, while David R. Layzer has been advanced from lecturer to professor.

Dr. Goldberg has accepted a joint appointment to Harvard and to the Smithsonian Astrophysical Observatory, and will be in charge of their space research program.

Other recent appointments in astronomy at Harvard have included Max Krook to the rank of professor. A. E. Lilley, who became an associate professor in January, is in charge of radio astronomy at Harvard's Agassiz station.

GETTING ACQUAINTED WITH ASTRONOMY

THE PLANETS — VENUS – I

AT ITS BRIGHTEST, Venus shines more brilliantly than any celestial body except the sun and moon. Of all the planets, it is most nearly the earth's twin in size and physical nature. But its heavy cloud-laden atmosphere is a great barrier to telescopic observations, and we know very little about conditions on its surface. Thus, although it approaches nearer the earth than any other principal planet, Venus remains enshrouded in mystery.

Added to Venus' fascination as a naked-eye object are its changing phases, which may be seen in even very small telescopes. But the indistinct markings of this cloud-veiled world are the subject of much controversy, offering difficult problems to skilled observers with the best equipment. They have not even been able to agree upon such a basic question as the rotation period of Venus.

Our sister planet revolves around the sun in a nearly circular orbit once in 225 earth days. But since the earth is traveling in the same direction along an exterior orbit, 584 days are required, on the average, for these two planets to return to the same positions relative to the sun. This is the synodic period of Venus, the length of time in which it goes through an entire cycle of its phases.

The phases are closely analogous to those of Mercury, described on page 221 of the February issue, where the diagram of the phases also applies (except for scale) to the case of Venus. The synodic period of Venus is more than five times as long as that of Mercury, although the ratio of the sidereal periods is about $2\frac{1}{2}$ to one.

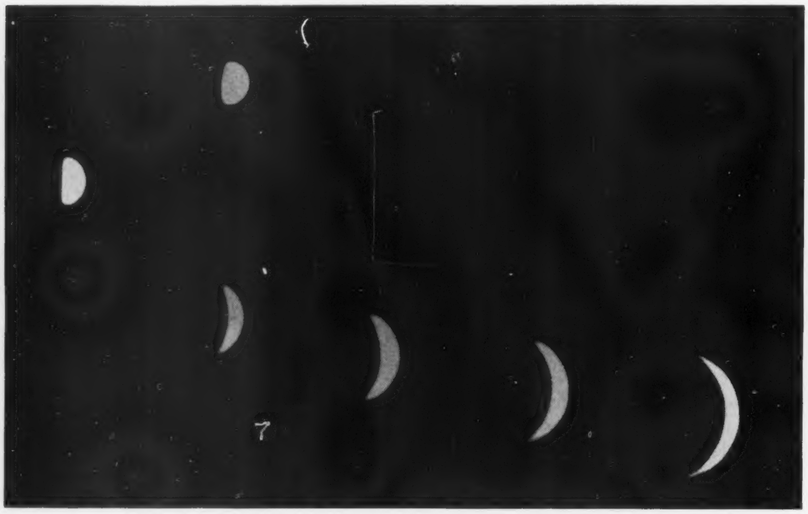
In the coming synodic period, on June 22, 1960, Venus is at superior conjunction beyond the sun, passing from the morning into the evening sky. Telescopically, its disk is then 10 seconds of arc in diameter, practically fully illuminated. As Venus moves farther into the evening sky, it is approaching the earth and growing in angular size, its phase being gibbous.

A conjunction of Venus with the moon is a beautiful spectacle which lends itself readily to photography with simple equipment. This series of exposures on the same film was taken by Jim Peters, Seattle, Washington, with a homemade camera that used a Zeiss lens of 150-mm. focal length.

Greatest eastern elongation, 47 degrees from the sun, is attained January 29, 1961, when the phase will be like the first-quarter moon. Venus will then be a striking sight in the western evening sky, remaining above the horizon several hours after twilight ends.

Thereafter, Venus rapidly nears the sun, attaining its greatest brilliance at apparent magnitude −4.3 on March 5th, when it will appear telescopically as a thin crescent. Thirty-six days later, on April 10th, the planet will reach inferior conjunction, entering the morning sky. Venus will pass seven degrees north of the sun, and will therefore remain visible as a very slender crescent, fully 61 seconds in apparent diameter because of its closeness to the earth.

Greatest elongation west of the sun occurs June 20th, the angular separation of the two bodies being 46 degrees. Thereafter, Venus will remain a morning object, gradually receding from the earth until it attains superior conjunction on January 27, 1962, having completed the phase cycle in 585 days.



These six photographs of Venus show how it changed from a gibbous phase to a narrow crescent, meanwhile growing in apparent size, between March 3 and June 8, 1956. Roland Rustad, Jr., of Minneapolis, Minnesota, used a 6-inch reflector to take these pictures, interposing a Barlow lens to obtain an effective focal length of 225 inches.

Compared to the richly detailed surface of Mars or Jupiter, the almost blank face of Venus can be a disappointing telescopic sight, even under favorable viewing conditions. There are, however, a few normally observable features, some perhaps being subjective in nature rather than actual details on the planet. In every case, the feature is merely a slight difference of contrast.

Often the tips of the crescent appear to be somewhat brighter than the rest of the disk, one cusp usually being more prominent than the other. There are frequent reports of changes in the size and brilliance of the cusp caps within a matter of two or three weeks.

Two other features widely reported are the limb band and terminator shading. The former is a narrow, bright strip along the planet's edge from one cusp to the other. The latter is a slight duskiness on the illuminated part of the disk, extending along the terminator.

Visual observers agree that other details occasionally glimpsed on Venus are much more difficult than those just mentioned. They are very faint tones, at the limit of recognition, with outlines usually too uncertain for sketching. Some observers,

particularly in Europe, have found that these vague light and dusky areas seem to persist for several days.

Much more definite results have been obtained by photography in ultraviolet light. This work was begun at Mount Wilson Observatory in 1927 by F. E. Ross. Other pictures in violet light by G. P. Kuiper at McDonald Observatory reveal clearly a pattern of dark and bright bands, evidently originating in the atmosphere of Venus.

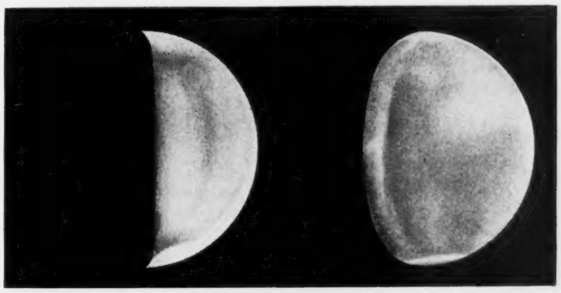
A good source of general information about Venus is Patrick Moore's book *The Planet Venus* (Macmillan, second edition, 1959), a detailed summary of findings written from the viewpoint of an experienced amateur observer. Surface markings, the rotation problem, and observational techniques are discussed, together with transits of Venus across the sun, although the next transit is not until June 8, 2004!

Any one discussion of so controversial a planet must necessarily be colored by its author's views. Hence it is advisable to consult also the important article by A. Dollfus in the November, 1955, issue of the French journal *L'Astronomie*.

Notes concerning Venus have appeared in Sky and Telescope from time to time, particularly in July, 1956, page 397; October, 1957, page 588 (see comments on page 179 of February, 1958); May, 1959, page 384; September, 1959, page 606; and April, 1960, page 343.

(To be continued)

EDITOR'S NOTE: Some of the material presented here was originally written by Thomas R. Cave, Jr., as a chapter in the observing manual at one time proposed for the Astronomical League.



Two drawings of Venus, made by Walter Villiger with the 10½-inch refractor of Munich Observatory on November 16, 1895, and March 21, 1896, respectively.

LETTERS

Sir:

There is an important omission in the account of instruments at the Leiden southern station in the Union of South Africa, on page 205 of the February issue. Mention should have been made of the close connection of the Leiden station with Union Observatory, ever since the former was founded in 1938. Also, for 15 years before that Leiden astronomers had regularly visited the Union Observatory, and were given the opportunity of using its instruments to obtain rich observational results.

The Rockefeller telescope was erected in 1938 on the grounds of Union Observatory, with considerable support from the South African government. When good photometric observations became impossible in Johannesburg, the same hospitality was extended to Leiden astronomers at the new annex of Union Observatory at Hartebeespoortdam, where its Franklin-Adams camera had been re-erected.

J. H. OORT
Leiden Observatory
Leiden, Netherlands

Sir:

A commercially available direct-vision spectroscope, consisting of a 10-inch tube with a three-millimeter slit at one end and a plastic replica grating (13,400 lines per inch) at the other, can be used to observe solar Fraunhofer lines. As a very narrow slit is necessary to resolve the lines, I mounted the edge of a piece of black paper over the instrument's slit, adjusting it by hand. The instrument has no lenses.

I looked at the sun with this arrangement and, much to my surprise, there were the absorption lines. All but one of the lines labeled in Fraunhofer's picture (page 345, April issue) could be seen, but the K line of calcium was too far in the violet to be recognized.

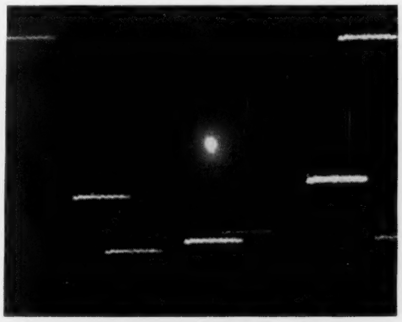
As a junior astronomer (age 13), I would like to correspond with other amateurs who have experimented along these lines. I am a member of the Burlington Astronomy Club, which is building a small spectroscope.

JAY FREEMAN
100 DeForest Rd.
Burlington, Vt.

Sir:

Otto Struve's article on visual observations of meteors (page 200, February issue) included a discussion of meteoric clustering. Horace T. Castillo and I worked on this problem for some time prior to 1956; our results were published in the November, 1956, issue of the *Ohio Journal of Science* under the title, "Clustering of Meteors as Detected by the Use of Radio Technique."

Our procedure was to receive the 20-megacycle signal of WWV as reflected from the ionosphere, and record it on an Esterline-Angus recorder. An incoming meteor would produce an instantaneous burst of signal strength due to ionization of the region making it a better reflector [see page 363 of last month].



Comet Burnham 1960a on January 28th. Elizabeth Roemer took this 50-minute blue-light exposure with the 40-inch reflector of the U. S. Naval Observatory's station at Flagstaff, Arizona. Then about magnitude 14, this comet is fading rapidly, and may be only about 18 by the beginning of May. Official U. S. Navy photograph.

The equipment had a limiting magnitude of 7 or perhaps 7½, so micrometeorites were not included. We recorded 175 bursts per hour, or about three each minute. In all, 1,308 bursts were recorded on nine nonshower nights in early 1956. Recordings were made between 2 and 3 a.m., when there was less interference.

In our statistical analysis of the counts, a Poisson distribution was fitted to the observations, 30 seconds being chosen as the time interval. In this way we found that the number of intervals having five, six, or seven bursts was far in excess of what would result from chance. Not more than three times in 100,000 would a random arrangement produce the observed distribution. It thus appears that on nonshower nights many clusters of meteoric particles strike the earth's atmosphere.

LLOYD R. WYLIE
Weaver Observatory
Wittenberg University
Springfield, Ohio

Sir:

My photograph of a comet taken on January 21, 1960, and published on page 298 of the March issue, is a picture of Comet Burnham 1959k and not of Comet Burnham 1960a. Since I had no information about the official designation of the object, I assumed on the basis of a newspaper account that it was probably 1960a. Only an hour after my exposure on 1959k, Robert Burnham at Lowell Observatory obtained the first record of the true 1960a!

The statement on page 298 that the motion was northward applied to 1960a; Comet 1959k was moving half a degree per day toward the west-southwest.

BRADFORD A. SMITH
Physical Science Laboratory
New Mexico State University
University Park, N. M.

OBSERVER'S PAGE

Universal time (UT) is used unless otherwise noted.

Observations of the March Lunar Eclipse

HUNDREDS OF REPORTS received by SKY AND TELESCOPE indicate that the total eclipse of the moon on March 13th was certainly one of the most widely observed by amateurs in North America, despite severe cold and considerable cloudiness. Although clear skies prevailed over most of the Middle West and the southern states, observers on the Pacific Coast and in New England and most of Canada fought overcast.

Few watchers could report "very comfortable observing conditions," as did R. F. Barnes at St. Augustine, Trinidad, where the thermometer read 72° Fahrenheit. At Huntsville, Alabama, G. F. Schmitz noted the temperature as 17° while he photographed the eclipse with a 16½-inch reflector. In Pennsylvania and Ohio, +8° to 0° prevailed, and E. Nordeen, St. Paul, Minnesota, observed at −8°, while T. Huston braved −10° at Shelby, Ohio.

Every active astronomical society realizes the value of an eclipse of the moon as a group activity and as a means of stimulating public interest. The Royal Astronomical Society of Canada deserves special mention. Its Montreal Centre organized an extensive program involving 14 observing stations and including searches for lunar meteors, timing of the contacts and of crater entrances into the umbra, and color observations, but this work was largely frustrated by clouds.

Similar plans had also been made by the Regina Astronomical Society in Saskatchewan, but were seriously hampered by fog. About 60 people visited its observatory despite the −9° cold. Miss B. L. Wilson, the club secretary, wrote: "The meteorological report will indicate the drop in temperature but does not tell about the sidereal drives that froze, or the ice that developed on the eyepieces, and the feet that rapidly grew numb. . . . At least the coffee industry did not do badly by the operation."

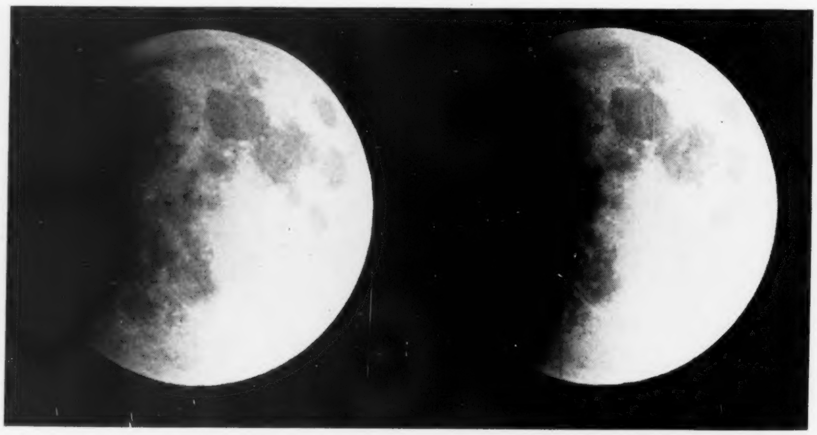
One of the busiest men during the eclipse must have been Ernst E. Both, at the Museum of Science in Buffalo, New York. Clear skies brought 650 visitors to look through the 8-inch refractor in his care, yet he managed to secure a long series of crater timings with the same instrument, and also took 25 photographs! On the roof of the museum, members of the Nichols School Astronomy Club used hectographed sheets for recording their observations.

At Union City, New Jersey, the Hudson County Astronomical League had 18 observers at work to secure a detailed record of the event. In addition to the group activities of many amateur societies, the astronomy departments of numerous colleges arranged student observations of the eclipse. Pictures on page 404 of this issue show some of the activities at Macalester College, in St. Paul, Minnesota.

One of the more elaborate student enterprises was by Ivan Aron's optics class at Heidelberg College, Tiffin, Ohio. His students spent 3½ weeks constructing a special camera for the event, and during the eclipse secured photoelectric observations with the college's 6-inch Clark refractor.

So numerous are the observational reports that it is impossible to publish them individually. The many careful studies of the eclipse by amateurs can be combined into the following synopsis, which also rests on the reports of some contributors not specifically named.

Darkness of the eclipse. The general consensus of observers on March 13th



These photographs are from a sequence of 28 obtained by Mark Johns at Cleveland, Ohio. The left-hand picture was taken at 1:45 a.m. Eastern standard time, the other 10 minutes later. Both were exposed 1/100 second on Plus-X film, in an Exakta 35-mm. camera attached to a 6-inch reflector.

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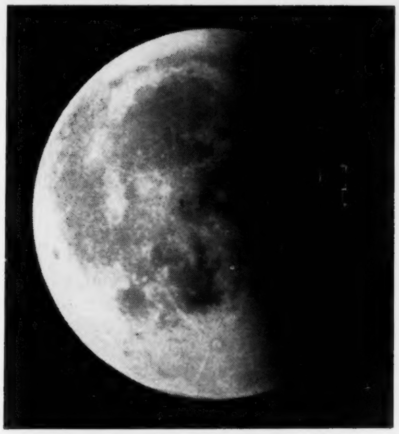


Observing with several members of the St. Paul Telescope Club, in severe cold, Lawrence M. Rogers took this and many other pictures, including about 12 color transparencies. For this 1/100-second exposure on Plus-X film, he used a 6-inch reflector and a Praktica single-lens reflex camera. Mr. Rogers rated the eclipse darkness, described below, as L = 2.

was that the moon during totality was neither unusually bright nor dark, but intermediate, compared with other recent eclipses.

As explained on page 229 of the February issue, the brightness of the totally eclipsed moon can be estimated on A. Danjon's five-point numerical scale, which extends from $L = 0$ for a very dark eclipse to $L = 4$ for a very bright one. Since the earth's umbral shadow is much larger than the moon, darkening from its edge to center, the estimated number varies during an eclipse.

However, there were 27 observers who noted L at or near mid-eclipse, none finding $L = 0$. Their results are distributed as follows: $L = 1$, 5; $L = 2$, 14; $L = 3$, 7; $L = 4$, 1. From this, Danjon's brightness number seems to have been about 2 for the March eclipse. The specific description of this value is "a deep red or rust-colored eclipse, with a very dark central part in the shadow, outer edge of the umbra relatively bright."

Visibility of surface features. Totality lasted from 7:41 Universal time to 9:16. During this long interval the lunar seas remained clearly visible in 7 x 50 binoculars (H. R. Klink, Roanoke, Virginia, and C. D. Naylor, Norristown, Pennsylvania), and in 6 x 30's (J. H. Knowles, Jamaica, New York, and R. Defouw, Port Washington, New York).

However, at Cleveland, Ohio, no craters could be seen in the umbra by V. J. Slabinski, with a 2-inch 5x refractor. Similarly, P. Hirschhorn, Great Neck, New York, noted that to him and four others, with a $3\frac{1}{2}$-inch reflector, "never once was there a crater plainly visible as other than a darkish or lightish area on the surface."

Larger apertures did show craters. K. J. Delano, Baltimore, Maryland, with his 4-inch reflector found Riccioli clearly visible; while T. Markin, Ft. Lauderdale, Florida, saw Grimaldi at 8:11 with a 6-inch. In a telescope of the same size, R. Conklin, at Richmond, Virginia, saw that the great ray extending northeast from Tycho was very conspicuous while in the earth's shadow.

Varying visibility of craters inside the umbra was recorded at Springfield, Illinois, by C. F. Capen, Jr., with members of the Sangamon Astronomical Society, employing a $12\frac{1}{2}$-inch reflector and other instruments. At 7:04 UT, only five minutes after entering the umbra, Copernicus had become invisible, and at 7:50 it, Tycho, and Aristarchus could not be seen. But at 8:55 all three craters were visible, together with the major lunar ray systems.

Throughout totality, the entire outline of the moon remained evident to the unaided eye, according to W. K. Hartmann, at State College, Pennsylvania. Furthermore, Mr. Markin reported the naked-eye visibility of Mare Crisium at 8:11.

Observations of the penumbra. One method of studying the faint outer portion of the earth's shadow is to note the time, before the beginning or after the end of umbral eclipse, when the penumbral darkening is first or last seen.

In J. Sunshine's naked-eye observations at University Heights, Ohio, the penum-

bra was first suspected at the moon's eastern edge 44 minutes before, and was definite 25 minutes before, first umbral contact. The corresponding intervals were 43 and 23 minutes for F. Pilcher, Lawrence, Kansas.

The penumbral darkening was initially noted 31 minutes prior to umbral eclipse by W. E. Baughman, Ft. Lauderdale, Florida; and 27 minutes before it by members of the Terre Haute Astronomical Society and Moonwatch Team in Indiana.

Another simple way of assessing the visible extent of the penumbra is to estimate directly the breadth of the shading, in terms of the moon's diameter. Mr. Capen did this at first and fourth contacts, finding in each case the apparent width to be two-thirds of the lunar diameter.

Color of the eclipsed moon. Many amateurs paid careful attention to the coloration of the moon while it passed through the earth's shadow. During mid-totality, about 8:28 UT, the center of the umbra was somewhat north of the middle of the moon's disk, and this was the most favorable time for assessing the color of the shadow's dark central core.

It was generally described as red brown, but the range of impressions and descriptions was wide. To cite only a few of these, Mr. Baughman recorded the core as "rusty orange-brown" (naked eye); T. Isbell, El Paso, Texas, "orange" (7 x 50 binoculars); A. Radzius, Baltimore, Maryland, "brown, with a reddish tone, like rusted iron" (naked eye); Mr. Defouw, "fairly dark orange" (naked eye); and S. S. Zeller, Buffalo, New York, "brick red with yellow border" (2.4-inch refractor).

W. L. Norton had perfect sky conditions at Ridgeville, Indiana, for his color observations with a 6-inch reflector and the naked eye. He saw the core as deep red, with a diameter one-third the moon's, and watched it cross the lunar disk during the course of totality. The core blended into a surrounding rust-colored zone that brightened continuously outward to its circumference.

One report warranting special attention is that of Wentworth Parker, Terre Haute, Indiana, because it describes the coloration seen by the trained eye of an artist. Mr. Parker used a 50-mm. finder as well as the unaided eye.

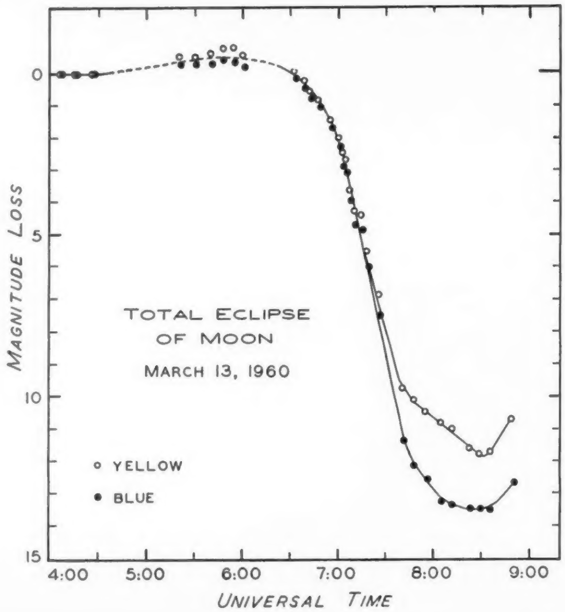
At a time when the umbral edge had advanced a quarter of the way across the disk, the eastern side of the moon appeared a pinkish copper, like iron getting hot, while the shadow boundary was neutral gray. But when the umbra was half on, this boundary was blue gray, the shadowing deepening inward through yellowish orange to copper shades. Lighter regions resembled burnt umber, darker ones raw umber.

Mr. Parker noted that when the shadow edge was three-quarters of the way across the disk the hues inside the umbra were

as before. The principal change was that the blue-gray shadow border was now tipped with thin turquoise-blue streaks at its northern and southern ends.

A number of eclipse watchers recorded a phenomenon perhaps related to this. L. Secretan, using 7 x 56 binoculars at Washington, D. C., saw just before totality began that the light copper umbra had a bluish edge. The same bluish edge was observed from 7:32 to 7:41 UT by R. Citron with a 5-inch refractor at Jupiter, Florida.

It attracted particular attention from J. Scatliff, at Winnipeg, Manitoba. "Throughout the latter half of the period between first and second contact, a distinct blueness preceded the dusky red of the umbral shadow. This blueness was a deep amethyst in color, not discernible except by the naked eye." At the onset of totality, he adds, the last glimmer of the west limb was light blue in a 2.8-inch refractor.



Donald Engelkemeir made these photoelectric measures of the central part of the moon during the March lunar eclipse. On the vertical scale, zero indicates the brightness of the uneclipsed moon, and the broken part of the curve shows when clouds impaired accuracy. During totality the sky was clear. Note the greater fading in blue light compared with yellow.

Is this bluish border merely a contrast phenomenon? Some amateur observers of the coming September 5th eclipse may be able to decide this question for themselves, by the use of suitable color filters.

Photoelectric and other special observations. At recent eclipses, professional astronomers have spent much effort in photometric measurements with photoelectric equipment, in order to study the distribution of light inside the earth's umbra. Nowadays, many amateurs have the instruments and electronic experience needed for such work, as the March 13th eclipse demonstrated.

The accompanying light curve was determined by D. Engelkemeir, Hinsdale, Illinois, with a 1P21 photomultiplier in the photometer of his 8-inch reflector. He measured repeatedly the brightness of a one-minute circular area in the middle of the lunar disk, using the star Beta Leonis as a standard. Although sky transparency was not good, he was able to determine that by mid-totality the area had faded 11.8 magnitudes in yellow light, and 13.5 in blue light. Mr. Engelkemeir used standard Johnson-Morgan color filters.

Other amateurs who made photoelectric

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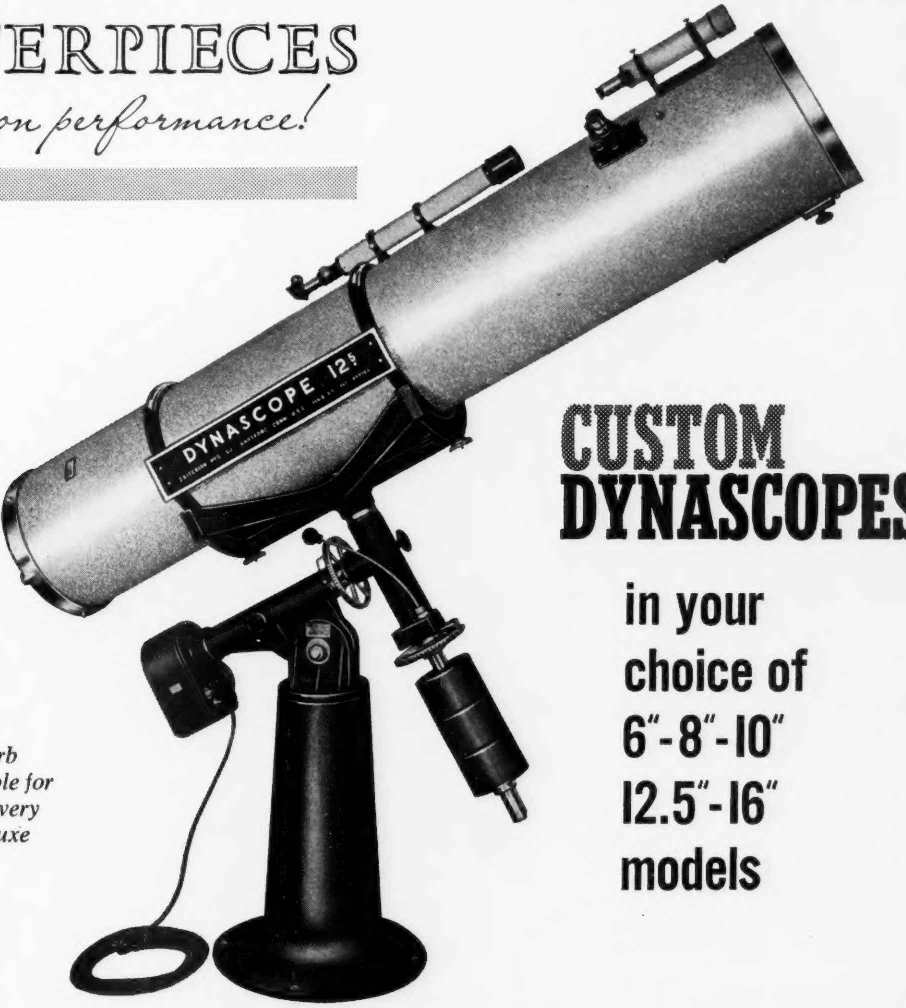

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observations were Mr. Baughman; P. Seldon, Dayton, Ohio; Mr. Norton; D. E. Laird, Centerville, Ohio; and M. A. Thomas, Seattle, Washington.

Mr. Norton's work was with a cadmium-sulfide cell at the focus of his f/9 6-inch reflector. Mr. Laird measured the total light of the moon with a Clairex CL-4 photocell, mounted inside a long tube to cut off stray light. His series, taken through a red filter, indicated that by the time of first umbral contact the moon's light had already diminished 25 per cent, because of the penumbra. However, seven minutes before totality began the moon became too faint for further readings.

Extensive photoelectric observations of the moon during eclipse were carried on at the Cactus Peak Observatory of the U. S. Naval Ordnance Test Station, China Lake, California. This station is one where regular photometric observations are made of the airglow. Selected portions of the moon were measured with the airglow photometer, attached to a 4-inch telescope. In addition, a 10-inch reflector was used for infrared measurements at four to five microns, the detector being a lead-sulfide cell.

Among the special observations planned for the March eclipse, searches for lunar meteors were scheduled by Canadian amateurs, but the weather was not suitable, as mentioned earlier. At Bellwood, Illinois, M. Francis and others carried out such a program, with negative results.

It should not be forgotten that a total lunar eclipse offers a chance for the discovery of small satellites of the moon that may be unobservable at another time. Clyde Tombaugh and others from New Mexico State University went to Lowell Observatory to make a search of this kind on March 13th, as they did in November, 1956, but it was cloudy.

A very large number of observations of contacts and crater times have been received by SKY AND TELESCOPE. A discussion of this material will appear in a later issue, together with an analysis to determine the amount of enlargement of the earth's shadow.

Thanks are extended to the many readers who have submitted reports and photographs of the eclipse. In many cases these accounts include the work of groups of people, and there are others whose names have not been reported to us who have nevertheless made important contributions.

J. A.

LIST OF CORRESPONDENTS ON MARCH LUNAR ECLIPSE

Photographs were received from those indicated by asterisks.

UNITED STATES

Alabama: *G. Schmitz, Huntsville.

Arizona: W. Coleman, Phoenix; *D. Strittmatter, Tucson; *E. Strittmatter, Tucson.

California: *J. Baumgardt and R. Bruce, Bakersfield; *U.S.N. Ord. Test Sta., China Lake; W. Westbrooke, San Francisco.

Colorado: D. Robertson, Boulder.

Connecticut: *F. Sulloway, II, Darien.

District of Columbia: J. Krebs, Washington; *L. Secretan, Washington.

Florida: W. Baughman, Ft. Lauderdale; *R. Citron, Jupiter; *Key Biscayne Astr. Assn., Key Biscayne; *D. MacDougal and D. Veal, Atlantic Beach; T. Markin, Ft. Lauderdale; F. Whitten, Jr., Panama City.

Illinois: J. Blair, Evanston; D. Engelkemeir, Hinsdale; M. Francis, D. Wells, M. Wells, and P. Wells, Bellwood; *Key Biscayne Astr. Assn., Ill. Branch, Elmhurst; *F. Klicar, Chicago; *P. Polko, Lyons; Sangamon Astr. Soc., Springfield; J. Skul, Joliet; P. Smelter, N. Riverside; *W. Winston, Chicago.

Indiana: *L. Deming and W. Parker, Terre Haute; W. Norton, Ridgeville; Terre Haute Astr. Soc. and Moonwatch Team, Terre Haute.

Iowa: *R. Cromwell, Des Moines.

Kansas: F. Pilcher, Lawrence.

Louisiana: *W. Searcy, New Orleans.

Maryland: Mrs. W. Cameron, Adelphi; K. Delano, Baltimore; E. Lerner, Pikesville; *M. Meyerhoff, Glen Burnie; A. Radzius, Baltimore.

Michigan: *F. Lewis, Royal Oak; *A. Morehouse, Battle Creek; G. Van Aken, Dexter.

Minnesota: *Macalester Coll., St. Paul; E. Nordeen, St. Paul; *L. Rogers, New Brighton; Star Gazers Club, Northfield.

Mississippi: J. Brownridge, Jackson.

Missouri: *W. Fullerton and H. Corwin, Kansas City.

New Jersey: G. Doherty, Wood-Ridge; C. Hossfield, Ramsey; Hudson County Astr. League, Union City; *R. Kimmel, Hillside; T. Massey, Cedar Grove; *H. Pfleumer, N. Brunswick; *L. Yuill, Hillside.

New Mexico: *Albuquerque H.S. Astr. Club, Albuquerque; *P. Hitt, Alamogordo; *D. Judd, Albuquerque; C. Tombaugh, Las Cruces.

New York: *R. Barnell and D. Zarzychi, Schenectady; H. Bondy, Flushing; E. Both, Buffalo; *Broome County Astr. Soc., Binghamton; *A. Burek, Hempstead; R. Defouw, Port Washington; *A. Fischetti, New Hyde Park; J. Fitzpatrick and K. Savage, New York; *W. Guido, Bohemia; *P. Hirschhorn, M. Blechner, J. Kaplan, R. Palmer, and F. Prisco, Great Neck; J. Knowles, Jamaica; P. Leavens, Freeport; *A. Linder, E. Rockaway; H. Luft, Oakland Gardens; Nichols School Astr. Club, Buffalo.

North Carolina: *Forsyth Astr. Soc., Winston-Salem; *J. Martin and D. Brotherton, Troutman.

North Dakota: *D. Bergquist, Fargo.

Ohio: *I. Aron, Tiffin; *Case Astr. Soc., Cleveland; *T. Huston, Shelby; *M. Johns, Cleveland; D. Laird, Centerville; Miami Valley Astr. Soc., Dayton; P. Seldon and M. Eisele, Dayton; J. Sunshine, University Heights; D. Weilant, Toledo.

Pennsylvania: *G. Bonney, Butler; *C. Dean, Narberth; *F. Delaney, Pittsburgh; G. Foley, Philadelphia; *L. Gearhart, Jr., Clearfield; *W. Hartmann, New Kensington; Marion Center Joint H.S. Astr. Club, Marion Center; *J. Markley and C. Schroth, Sellersville; C. Naylor, Norristown; J. Shannon, Kittanning; *D. Whitmarsh, State College.

South Dakota: *R. Dyvig, Deadwood.

Texas: *T. Bates, Odessa; C. Isbell, El Paso.

Virginia: R. Conklin and F. Clark, Richmond; *A. Creutz, McLean; E. Jones and G. Vetrovec, Sandston; *H. Klink, Roanoke; Richmond Assn. of Jr. Astronomers, Richmond.

Washington: M. Thomas, Seattle.

West Virginia: *G. Cunningham and T. Barringer, Charleston.

Wyoming: H. Grams, Gillette.

BRITISH WEST INDIES AND BAHAMAS

R. Barnes, Trinidad; A. Wittmann, Nassau.

CANADA

British Columbia: *F. Cushing, Richmond.

Manitoba: Royal Astr. Soc. of Canada, Winnipeg Centre, Winnipeg; *J. Scatliff, Winnipeg; *B. Shinn, Winnipeg.

Quebec: Royal Astr. Soc. of Canada, Montreal Centre, Montreal.

Saskatchewan: T. Macfarlane, Regina; Regina Astr. Soc., Regina.

COSTA RICA

J. Sutcliffe, San Jose.

MEXICO

H. Rodriguez, Ciudad Juarez.

NETHERLANDS ANTILLES

*G. Heillegger, Curacao.

NEW ZEALAND

I. Thomsen, Wellington.

MARCH AURORA

THREE NIGHTS after the March 12-13 lunar eclipse, from about 7 p.m. to midnight, observers mainly in the northeastern United States were treated to a predominantly greenish aurora. However, at Rapid City, South Dakota, Roy LaBelle reported observing the event. He first detected auroral activity at 9:20 p.m. Eastern standard time by means of radio disturbances on 50 and 144 megacycles; because of haze and clouds, visual observations were not possible until 25 minutes later.

The March 15th northern lights were extensively followed by Richard Defouw and Richard Miles at Port Washington, New York. They reported that from 8:15 to 9:00 a homogeneous arc stretched from a few degrees west of Cassiopeia to below Alkaid in the Big Dipper. Maximum activity occurred during the quarter hour after 9 o'clock, when about six sets of pale green rays and streamers appeared. At 9:06, bright green curtains covered the northern sky, and a minute later a faint red glow was seen at their eastern extremity. The drapery effect then became pronounced, with two nearly overlapping sets of rays, the lower pale green, the upper red.

Other amateurs who sent in reports are Roger Gendron, Old Orchard Beach, Maine; Richard T. Inman, S. Farmingdale, New York. Pennsylvania amateurs who reported are Allen Burstiner, Etters; Robert Cresko, Kingston; David Czarick, Pottstown; Lewis Dewart, Sunbury; and William Hartmann, who observed at State College.

William K. Hartmann took this 48-second exposure of the March 15-16 aurora at State College, Pennsylvania, at 9:04 Eastern standard time. It shows rays in the north. His 35-mm. Leica camera was set at f/2, and Agfa Isopan Record film was used, development being for an ASA rating of 800.

At the end of March, a sudden outburst of sunspots and other solar activity caused a three-day Special World Interval to be called. A number of reports of evening auroral displays on April 1-2 and 2-3 have been received from amateur astronomers in the northeastern part of the United States.

SUNSPOT NUMBERS

The following American sunspot numbers for February have been derived by Dr. Sarah J. Hill, Whitin Observatory, Wellesley College, from AAVSO Solar Division observations.

February 1, 186; **2,** 184; **3,** 187; **4,** 164; **5,** 171; **6,** 150; **7,** 128; **8,** 118; **9,** 161; **10,** 157; **11,** 142; **12,** 113; **13,** 103; **14,** 104; **15,** 63; **16,** 66; **17,** 47; **18,** 49; **19,** 40; **20,** 39; **21,** 61; **22,** 59; **23,** 57; **24,** 61; **25,** 52; **26,** 115; **27,** 87; **28,** 64; **29,** 64. Mean for February, 103.3.

Below are provisional mean relative sunspot numbers for March by Dr. M. Waldmeier, director of Zurich Observatory, from observations there and at its stations at Locarno and Arosa.

March 1, 52; **2,** 57; **3,** 71; **4,** 76; **5,** 74; **6,** 79; **7,** 108; **8,** 111; **9,** 109; **10,** 109; **11,** 82; **12,** 68; **13,** 85; **14,** 76; **15,** 84; **16,** 106; **17,** 86; **18,** 85; **19,** 102; **20,** 97; **21,** 115; **22,** 128; **23,** 145; **24,** 123; **25,** 128; **26,** 133; **27,** 146; **28,** 139; **29,** 154; **30,** 142; **31,** 138. Mean for March, 103.5.

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QUESTAR NEWS • *April-May, 1960*

This little fellow is a flying squirrel, a nocturnal native of Sarasota, Florida. Mr. and Mrs. Ralph Davis encourage his visits to their bird feeder by putting out a slice of bread each night. This model fee works so well they now have three regular customers.

In order to show how very tiny the flying squirrel really is, Mr. Davis set up this steel ruler behind the piece of bark which conceals the feeder dish. We find our eyes are so stubborn that they present a problem. The Davis prints are size 8 x 10, which makes this tiny squirrel more than twice life size on them. But no amount of effort can persuade our eyes to regard him as only 2 inches high. The enlarged flying squirrel is plain ordinary squirrel size, our eyes say, and they refuse to let us imagine the true size of the little beasts. When we reduce the picture to actual size, we have no trouble. This forcefully illustrates to us once more the great complexity of human vision.

This grainless photograph, which shows each hair and great detail of bark, was made with the Davis' Questar on ADOX KB-14 35-mm. film with strobe light. The camera is deep in the house, 30 feet from the outdoor feeder, which is outside a plate-glass window. The two electronic flash units are inside the window, out of the weather. This setup has long been used for photographing birds in color. The advantages are that once lights are correctly placed and cameras focused, every exposure is a perfect one. Birds do not react at all to the very brief and brilliant flash.

Questar owners are aware that most windows, even those of plate glass, seriously degrade the image. Ordinary window glass is particularly bad. We have ascribed the high resolution in pictures like the above to the fact that the plate glass was very near the object and quite far from the telescope.

A few weeks ago, we received a phone call from Mr. Gerould of the Chase Manhattan Bank, second largest in the country. He told us that they were building the world's sixth tallest building, whose 60th floor now dominates the Wall Street district where it stands. It is also the highest building built for 25 years.

An officers' restaurant will be located on the north side of the 60th floor, overlooking all of Manhattan from river to river, a truly breathtaking sight. It had been decided, said Mr. Gerould, to mount two Questars so the bankers could examine this grand scene through the plate-glass windows. Would we bring up a Questar and test the quality of plate glass, to determine whether special quality plate was necessary? Indeed we would, for we were most curious ourselves.

Arriving there we were taken to the 48th floor on a fairly clear day, and to our great satisfaction found the standard Libby-Owens-Ford plate glass entirely satisfactory. With Mr. Gerould we found that the glass interfered but little save at 160x, and even at this high power was no great drawback to observing. Views at Questar's 40x and 80x (actually 48x and 96x) were quite acceptable, both near and far from glass at various angles to it.

As we understand it, modern plate glass is made on a continuous basis, being simultaneously ground top and bottom while in motion. We can attest its clarity, parallelism, and freedom from strain. The interesting things that might be done by way of indoor observing, provided specially selected extra-high quality sheet were available, leap at once to mind. O man — to stay indoors, snug and warm, while perfectly free to observe the heavens — that is living! We know, for we once had a polar telescope, a 6-inch refractor over a 12-inch flat. Since the cold open end was down, tube currents were practically nil. Warm air stayed near the eyepiece, without moving, since the ocular was upstairs and indoors where it was warm. The trouble with conventional refractors, of course, is that the highest point is the coldest, due to radiation, which promotes a constant internal convection current of air, to the detriment of seeing, as W. H. Pickering pointed out many years ago.

Mr. Arthur Page, president of the Astronomical Society of Queensland, has most graciously sent us the following anecdote: Prof. Bart J. Bok, the director of Mount Stromlo Observatory, and Mrs. Bok were guests of honor of the Queensland Society on June 17, 1959. As the 4 members of the reception committee awaited the guests' incoming plane at the airport, they suddenly realized that none had ever seen their distinguished guests. Then someone remembered that Dr. Bok had promised to bring his Questar, so they decided to *"look for the Questar case — he must be carrying it by hand! Sure enough, identification and recognition were simultaneous. Clutched firmly in Prof. Bok's right hand was the case containing the Questar. A few minutes later when informed of this, Prof. Bok turned to Mrs. Bok and said 'Priscilla, we go home! They seem more interested in the Questar than in us!'* No *little wonder that our guests of honour endeared themselves to us with their charm and sense of humour.*

. . . "The highlight of the Society's Centenary celebration was Dr. Bok's address to the Institute of Physics and the Society at the University of Queensland, on 'The Structure of Our Galaxy.' . . . At this meeting also, members of the Society obtained their first look at Prof. Bok's Questar, which he left in the Society's care during his visit."

In early 1959, when the splendid current model of the Linhof heavy-duty tripod was introduced, it was in very, very short supply. We had so much difficulty getting shipments from Munich that we finally put in a whacking big order for several dozen to be shipped here to our factory, as sort of a reserve supply over the number held for us in New York by the importer. As of January, 1960, the price of the tripod jumped from $139.50 to $179.50, and the pan head rose by $10 to $69.50. By the time this page is printed we may still have a few left at the old prices. Our policy is not to raise the price of any item until we have to purchase more at the higher price. So while our supply of tripods lasts, we will pass the savings on to you.

Speaking of rising prices, the cost of each Questar part keeps on upon its steady rise. The average increase is perhaps 8% or so per year. A few sharper rises last year brought us face to face with the probability of having, after 5 years, to raise Questar's price.

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BOOKS AND THE SKY

THE TRANSITS OF VENUS

Harry Woolf. Princeton University Press, Princeton, N. J., 1959. 258 pages. $6.00.

FEW if any living astronomers have ever seen a transit of Venus. The last such events occurred in 1874 and 1882, while the next will not take place until 2004 and again in 2012.

The rarity of this phenomenon is caused by the inclination of Venus' orbit, 3° 36′. Venus passes inferior conjunction every 1.6 years, but usually it goes above or below the line between the earth and the sun. For a transit to take place, the planet must not only be at inferior conjunction, but must lie sufficiently close to one of its nodes, which it has one chance in 50 of doing. Therefore a passage of Venus in front of the sun occurs, on the average, about every 80 years.

At present the transits have a regular cycle of 243 years, in which the successive intervals are 8, 121½, 8, and 105½ years. Alert readers will notice that transits are happening more frequently than twice in 160 years. Sometime in the future, however, these events will come singly rather than in pairs, so that over thousands of years the 80-year average will be preserved.

About 350 years ago Edmund Halley pointed out that the distance to the sun could be determined from observations made of this phenomenon at widely separated geographical locations. Impressive efforts have been made to observe each of the four transits since the time of Halley's suggestion. Numerous memoirs and monographs have discussed these observations and their reduction.

It may seem strange to have a 258-page volume, devoted to two transits of Venus, in which the astronomical results are only incidental. Dr. Woolf's scholarly book is concerned primarily with the organization and development of science in the 18th century, rather than with specific observational findings. The scope of this valuable contribution is clearly revealed by its subtitle, "A Study of Eighteenth-Century Science."

The world's scientists eagerly awaited the transits of 1761 and 1769, for these phenomena gave an exceptional opportunity to evaluate one of the fundamental astronomical constants, the solar parallax. With this constant determined, the distance scale of the solar system would become accurately known for the first time.

These two transits brought into being the first major example in history of international co-operation in science. Through the efforts of the Royal Society of London, the Académie des Sciences in Paris, and many other scientific organizations, astronomical expeditions were sent to every part of the world to observe the transits of 1761 and 1769. Siberia, Java, India, California, Canada, South Africa, and the South Pacific were visited by observing parties, while Europe was covered by a network of stations.

There were high hopes that this enormous effort would settle decisively the problem of astronomical distances. Dr. Woolf quotes one of the leading English instrument makers of that time: "If we make the best Use of each [of the transits of Venus], there is no doubt but Astronomy will, in ten Years Time, attain to its ultimate Perfection."

Unfortunately, the observations showed much more disagreement than was anticipated. The atmosphere of Venus causes a black-drop effect that prevents accurate timing of the apparent contact of planet and sun. Difficulty was encountered in determining correctly the longitudes of the observing stations, and no one understood the amount of variation introduced by individual observers (the so-called personal equation). Furthermore, the combination of all the observations to yield the most probable value of the solar parallax could not be made until the method of least squares came into use two generations later.

The variety of source material in *The Transits of Venus* casts light on the nature of 18th-century science. During that period scholarly journals became an important means of communication. Many of the more than 500 references are found in the *Memoires de l'Académie Royale des Sciences* (Paris) and in the *Philosophical Transactions* (London). Another significant body of source material consists of unpublished manuscripts at observatories and scientific societies. The numerous footnotes show consultation of modern works as well as those contemporary with the transits.

OWEN GINGERICH
Harvard Observatory

LAROUSSE ENCYCLOPEDIA OF ASTRONOMY

Lucien Rudaux and **G. de Vaucouleurs.** G. P. Putnam's Sons, New York, 1959. 506 pages. $15.00.

WITH its lucid explanations amplified by almost a thousand beautiful diagrams and photographs, this book gives the reader many delightful hours and rewards him with a basic knowledge of practically all phases of astronomy. And if the reader carries the volume with him (as I did for a month in finding moments to read it), he will need little further exercise. Whether intentionally or not, the mass of the tome turns out to be almost exactly 10^{-30} that of the sun!

In his introduction, Fred L. Whipple enlarges on the idea that man's cultural development has proceeded in proportion to his comprehension of the nature of the world and the universe. He also

gently suggests that in certain areas the book is not up to date, and this reviewer notes that the most surprising omission is of important findings concerning comets and meteors by Whipple and his coworkers. However, for the most part the book has lasting value.

Book I, the first of the four parts that make up the volume, is entitled "The Splendour of the Heavens." Various types of celestial objects and their organization into progressively more complex units of the cosmos are described. Motions are beautifully illustrated, and the laws of Newton and Kepler are explained, but Kepler's third law is incorrectly stated on page 17. Also covered are such topics as the Foucault pendulum, precession and aberration, time and the seasons, and celestial co-ordinates. I suspect that Figs. 98 and 99 should be labeled "Sunset at the solstices" and "Sunset at the equinoxes," respectively, and a reference to them added in the middle of page 43 of the text.

"The Empire of the Sun" is Book II, occupying half of the total volume. It begins with an account of the discoveries of the outer planets. Beautiful drawings show the relative sizes of the planets and their variations in apparent diameter as seen from their extremes in distance from the earth. The chapter on the moon contains many fine drawings and photographs, and a general map locating 184 craters in addition to the maria and mountains. The opinion is expressed that craters and other surface phenomena are more likely the result of the upsurge of viscous magma through fissures than the remains of meteoritic impacts. A color plate of the moon during eclipse tempts one to cut it out for framing.

In the chapter that describes the planets individually, there is a very thorough treatment of Mars. One wonders how Kuiper's work could have been overlooked, when the statement is made that we have no knowledge of the tilt of Venus' axis. The chapter on comets does not mention Whipple's icy-conglomerate model, nor the curious effects of evaporation on comets' orbital motions, when the nuclei rotate in the same and the opposite sense to the revolution. Similarly, the meteor chapter is shockingly out of date in presenting the old visual evidence for large numbers of hyperbolic orbits, and in ignoring the modern evidence, from radar and super-Schmidt cameras, that such orbits are extremely rare.

Chapter 10 considers in great detail the sun and all of its complexities. American readers will be disappointed to find no reference to the classical researches by A. E. Douglass on tree rings. At the close of Book II, the isolation of the solar system and the general emptiness of space are described, and it is stated that the majority of stars have diameters greater than a million miles. This might be true of those that can be seen with the naked eye, but due to the preponderance of dwarf stars our sun is above average, even though its diameter is less than a million miles.

Book III, "The Realm of the Stars," suffers from lack of final revision to bring it up to date and make it self-consistent. There is a good section on catalogues, magnitudes, motions, and distance measurements. The various types of double stars and what can be learned from them are well presented, including the exciting discovery of invisible astrometric companions. Except for omissions, such as flare stars, variables are well treated, with a clear account of the Cepheid dual period-luminosity relation and its far-reaching implications.

An excellent introduction to astrophysics is afforded by the two chapters on the physics of the stars. The chapter on our galaxy tells of the difficulties caused by light absorption, and how these are met by Wolf diagrams and radio observations. But the treatment of extragalactic nebulae and the expanding universe appears to have been written around 1945. Distances and times are on the old scale, and there is no mention of the theory of continuous creation of matter.

The closing portion of the book is on astronomical instruments and observing techniques. A chapter on spectroscopic analysis and its astronomical applications will be a gold mine to many readers who would like to know how spectral lines originate in atoms and molecules, how stellar spectra are obtained, and what amazing things can be gleaned with the aid of the Doppler effect and studies of line profiles.

A short final chapter by de Vaucouleurs summarizes the philosophical, scientific, and technical values of astronomy. One cannot examine this remarkable book without a deep feeling of gratitude to its authors.

WILLIAM A. CALDER
Bradley Observatory
Agnes Scott College

THE UNITY OF THE UNIVERSE

D. W. Sciama. Doubleday and Co., Inc., Garden City, N. Y., 1959. 228 pages. $3.95.

IN this volume, a young British astronomer who was a student of Fred Hoyle presents modern views on cosmology for nonspecialist readers. Although the author has divided his book into two parts, one describing the observed facts of astronomy and the other "the universe in theory," this reviewer finds its contents fall more naturally into three sections.

Dr. Sciama begins with five chapters that quickly review the problems of measuring the solar system, stellar distances, the Milky Way, galaxies, and the expanding universe. These brief 62 pages give one of the clearest treatments of the determination of astronomical distances I have seen. Readers who seek a straight-

forward and understandable treatment of this subject will find the book well worth procuring for this part alone.

But beginning on page 87, the going is much more difficult, yet only because some mental effort is needed to digest the concepts discussed by Dr. Sciama, and not because of any shortcomings in his explanations. In six chapters he tells in simplified form about topics such as Olbers' paradox, the origin of inertia, the clock paradox, and the general theory of relativity. Despite the readability of these 79 pages, the subjects are not presented in such a way that "they can be understood without a formal background in physics or astronomy," as the book's jacket claims.

This quotation is based on the author's own statement in his preface, where he asks merely that the reader have a willingness to follow an argument to its logical conclusion. He avoids mathematics only by selecting certain characteristics of the principles he describes. While the reader may feel he is following the discussions, he should beware of assuming that he then understands the workings of the actual principles involved. There is no short cut to such understanding.

The third and final part, of 55 pages, surveys the broad cosmological problems that so many educated people like to read about nowadays. Dr. Sciama very fairly outlines the pros and cons of the steady-state universe versus the evolving universe, but leans toward the former. To him, a satisfactory theory of the universe should be comprehensive, reducing to a minimum the number of accidental phenomena. Hence he favors the idea of the continual creation of new matter, as suggested by the British cosmologists H. Bondi, T. Gold, and Hoyle.

The author writes: "We seek a theory which describes all that actually happens, and nothing that does not, a theory in which everything that is not forbidden is compulsory."

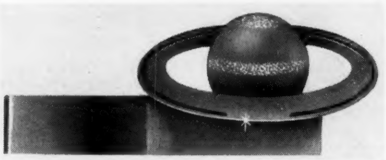
In this last section, Dr. Sciama discusses first the uniqueness of the universe, the origin of galaxies, and finally the origin of the elements. Though the treatment is brief, it gives about as much as the average reader may want to know about subjects that are so controversial and changing so rapidly.

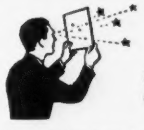
Sixteen pages of halftones in the middle of the volume show a wide range of well-printed but familiar astronomical photographs. The remaining illustrations are small, rather coarse line drawings that nevertheless fit well with the text. An important diagram on page 82 demonstrates to the reader that there is no unique observable center to the expanding universe — no matter where in the universe an observer is located, the galaxies appear to be receding from him. This diagram should find its way into textbooks on astronomy, where its equivalent is unknown to me.

Perhaps the most interesting chapters in the book for the thoughtful reader are VI, on Olbers' paradox, and VII, on Mach's principle. These important concepts are seldom mentioned in books on general astronomy.

Heinrich Olbers (in 1823, not 1826) noted that if infinite space is uniformly populated by stars, the sky should be dazzling, its surface brightness equal to that of the stars themselves! He concluded from this that some kind of interstellar fog was dimming the distant stars. We know now that there is not enough interstellar absorbing matter, and Dr. Sciama explains that the solution to the problem is to give up Olbers' assumption that the stars have no systematic motion. "It is dark at night because the universe is expanding." It is even possible, he notes, to estimate Hubble's constant of expansion from the amount of light of the night sky.

This reviewer cannot go along with the hindsight indictment that Olbers' failure to make this interpretation was "one of the greatest missed opportunities in the whole history of science." This expression is glib and inconsiderate; Dr. Sciama should instead have explained why the notion of an expanding universe was utterly alien to the intellectual climate of Olbers' day, and could not have taken root then. C. A. F.





NEW BOOKS RECEIVED

THE INTERNAL CONSTITUTION OF THE STARS, *A. S. Eddington,* 1959, *Dover.* 407 pages. $2.25, paper bound.

Now available in reprint form, Eddington's famous classic of 1926 is a lucid development of the problems of stellar structure.

THE THEORY OF OPTICS, *Paul Drude,* 1959, *Dover.* 546 pages. $2.45, paper bound.

Geometrical and physical optics are covered in a famous textbook first published in German in 1900 under the title *Lehrbuch der Optik.* This is a reprint of C. R. Mann and R. A. Millikan's translation of 1902.

VOYAGES TO THE MOON, *Marjorie Hope Nicolson,* 1960, *Macmillan.* 297 pages. $1.75, paper bound.

A Columbia University scholar tells about fictional travels to the moon in writings from the ancient Greeks to H. G. Wells. This is a reprint of a book first issued in 1948.

KEPLER, *Max Caspar,* 1959, *Abelard-Schuman.* 401 pages. $7.50.

Max Caspar, who died in 1956, spent many years in studying the life and work of Johannes Kepler, and published a definitive biography of the famous astronomer in 1948. It has now been translated from German into English by C. Doris Hellman.

LES OBSERVATOIRES ASTRONOMIQUES ET LES ASTRONOMES, *Fernand Rigaux,* 1959, *Observatoire Royal de Belgique,* Brussels, Belgium. 452 pages. £1, paper bound.

This is a directory, in French, of the world's observatories and their equipment and personnel. It is a revision and enlargement of the 1931 publication of the same name by P. Stroobant. Orders for this book should be addressed to the International Astronomical Union, Royal Greenwich Observatory, Herstmonceux Castle, Hailsham, Sussex, England.

VISTAS IN ASTRONAUTICS, VOL. II, *Morton Alperin* and *Hollingsworth F. Gregory,* editors, 1959, *Pergamon.* 318 pages. $15.00.

Papers presented at the second annual astronautics symposium, sponsored by the Air Force Office of Scientific Research and the Institute of Aeronautical Sciences in April, 1958, are printed in this volume, devoted largely to technical problems of space-flight.

Of particular interest to astronomical readers is a 59-page section on the moon. T. Gold and F. L. Whipple have contributed chapters on the moon's surface layer of dust. G. P. Kuiper describes the nature of the lunar surface as observed with very large telescopes, presenting in his 41-page article 23 fine photographs of detailed regions on the moon.

DIE FERNROHRE UND ENTFERNUNGSMESSER, *Albert König* and *Horst Köhler,* 1959, *Springer-Verlag,* Heidelberger Platz 3, Berlin-Wilmersdorf, W. Germany. 475 pages. DM 88.

Telescopes and Rangefinders is the third edition of a manual in German on precision optical instruments, by two scientists of the Carl Zeiss Works. There are discussions of basic optics, properties of the eye, the construction and testing of telescopes of many kinds, and details on specialized devices such as coronographs, micrometers, theodolites, periscopes, and bomb sights. The 471 diagrams and photographs show the principles and construction of a wide variety of individual optical systems.

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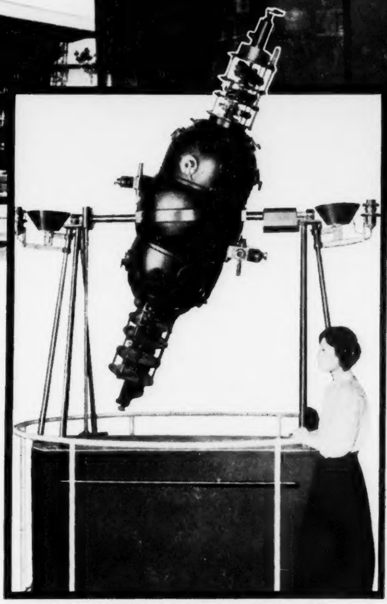

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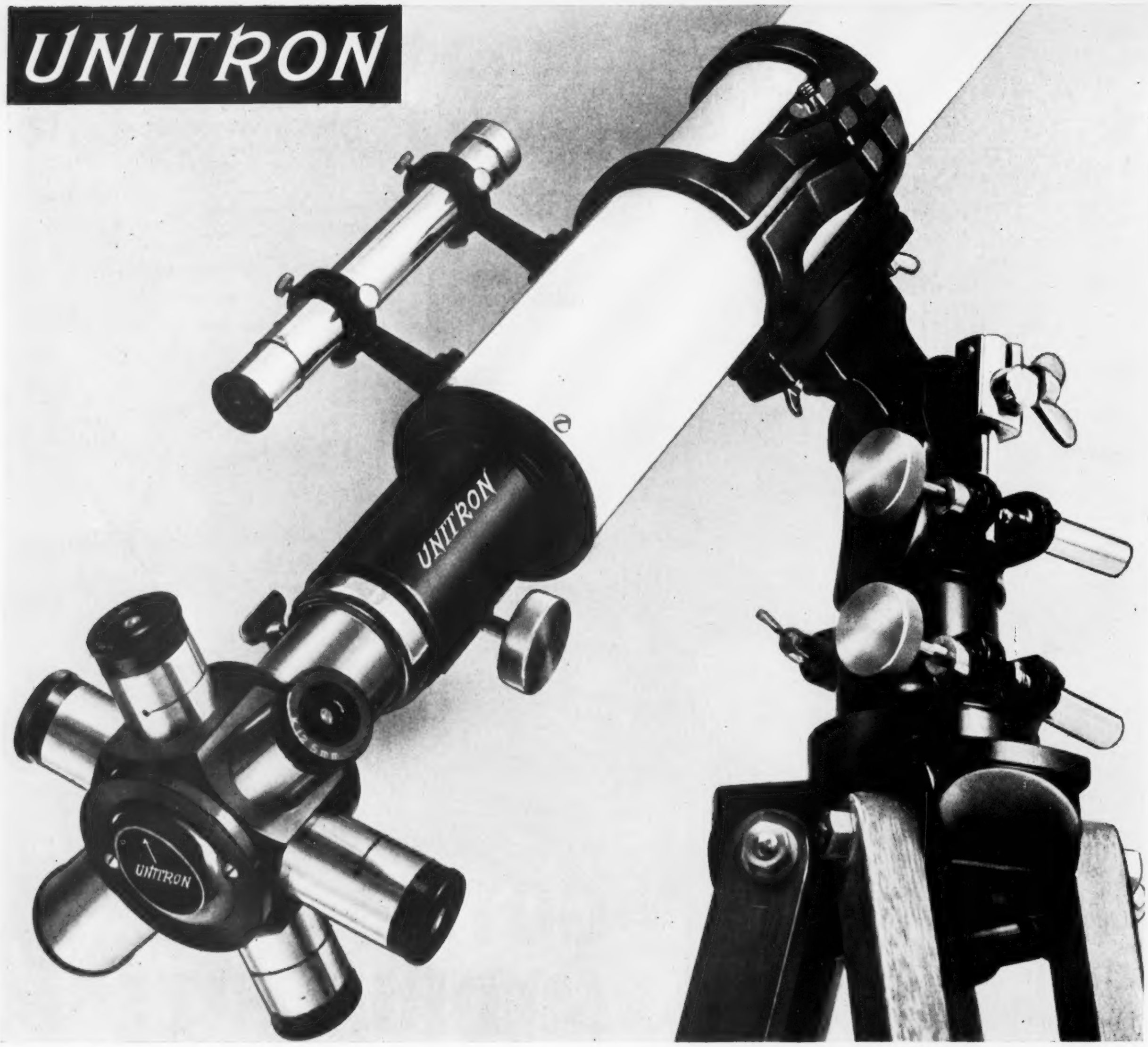

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CONDUCTED BY ROBERT E. COX

THE MEMPHIS ASTRONOMICAL SOCIETY OBSERVATORY

THROUGH the efforts of several members, a research station equipped with an 8-inch reflector has been provided for the Memphis Astronomical Society. The building is located in a field several miles outside of Memphis, Tennessee, and observing conditions are quite good, with practically no interference from the city's lights. This entire project took three years of spare time to complete.

A 9' galvanized-metal silo dome on a square enclosure of concrete blocks provides an adequate shelter for the telescope. White masonry paint on the outside of the building reflects light and heat effectively, and no great change in temperature takes place when the dome is opened at night. The slit is 30" wide and has two shutters, one hinged at the bottom and one at the top. When they are closed, they lie tightly against a rubber lining, making an effective weather seal. Due to the ample slit width, the dome needs turning only once about every three hours during periods of observation.

The floor consists of a 9'-by-9' concrete slab, in the center of which is a 5" pipe extending 4' into a bed of concrete. This telescope pier is also filled with concrete, for increased stability. Although there are only 81 square feet of floor space, the design of the observatory permits a small darkroom in the southeast corner and a table in an adjoining corner.

About four years ago, Dr. Carl K. Seyfert at Vanderbilt University told us that the Watkins Institute in Nashville had an 8-inch reflector for sale. Only the mounting and mirror proved to be in good condition, but our society decided to purchase them.

Billy Gooch, a machinist and club member, did most of the actual machine work, as well as the designing of the telescope, sidereal drive, and many of the accessories. The telescope was built and assembled in his back-yard machine shop before it was mounted in the observatory.

An open-type tube of 24 ⅜" pipes and four steel rings was constructed. The pipes were threaded internally and connected by nipples. With this arrangement the pipes look like six rods extending the length of the tube. At the upper end, six cap screws hold the top ring in place, while others at the lower end hold the mirror cell. The six pipes that make up the top section of the tube are stainless steel. Thus the spider, eyepiece holder, and accessories can be attached without marring the finish. This tube is easier to counterbalance than a closed one, since weights can be clamped on the rods.

The three-legged stainless-steel spider can be moved up and down the tube on small ball bearings, allowing the focal plane to be placed over a wide range of positions — a great convenience in attaching accessories at the Newtonian focus. The eyepiece holder is also mounted on two ball bearings, which allow it to slide in conjunction with the spider.

Little work was required on the mounting; we added two ball-thrust bearings on each axis to reduce friction, and lengthened the right-ascension axle to permit

Standing before the Memphis Astronomical Society's observatory is Billy Gooch, while the author, Michael Snowden, holds his pet lion.

attachment of a 12" clock-drive wheel.

Our nearly completed drive mechanism is hydraulic, to eliminate drive-rate errors caused by irregularities in gears. Around the 12" wheel on the end of the polar axle are wound two cables. One is wrapped a single turn in a counterclockwise direction, the other a turn clockwise. The first cable is attached to the piston of the hydraulic cylinder, while the second passes through an underground tube to one corner of the observatory and by means of ball-bearing pulleys up the side wall and down to a 60-pound weight. This weight pulls the telescope in a westerly direction, its rate of descent being controlled by the piston in the cylinder.

The piston's motion is governed by the amount of fluid entering the system through three solenoid needle valves. A push-button control activates the valves, which act like the slow-motion differential in an electric drive, while the instrument can be moved rapidly with a clutch arrangement at the 12" wheel. With this piston device the solenoid action is fast, and the fluid viscosity virtually eliminates coasting. The cylinder is long enough so that resetting is required only once in eight hours — sufficient for an evening of observing.

I have used this telescope, without drive, for two projects. The first was visual and photographic planetary observing with a CV147 photoelectric image tube. The range of sensitivity of the tube is 3000 to 10,000 angstroms, and by choosing appropriate filters it is possible to observe in the infrared and ultraviolet. Despite insensitivity of the tube, ultraviolet observations of Venus were made by keeping the image small, so it was intense enough on the photocathode for a good response.

The second project used a 16-mm. movie camera for lunar and planetary photography, the camera's shutter being replaced with one from a still camera to permit a variety of exposure times. Two cable releases were used, one advancing the film a frame at a time, the other tripping the shutter. In addition, the camera's regular shutter allowed pictures at 16 frames per second.

In both experiments, a positive lens was used to change the effective focal length of the instrument, giving a wide range of powers. This arrangement was discussed in this department last November by Dr. Sherman W. Schultz, Jr.

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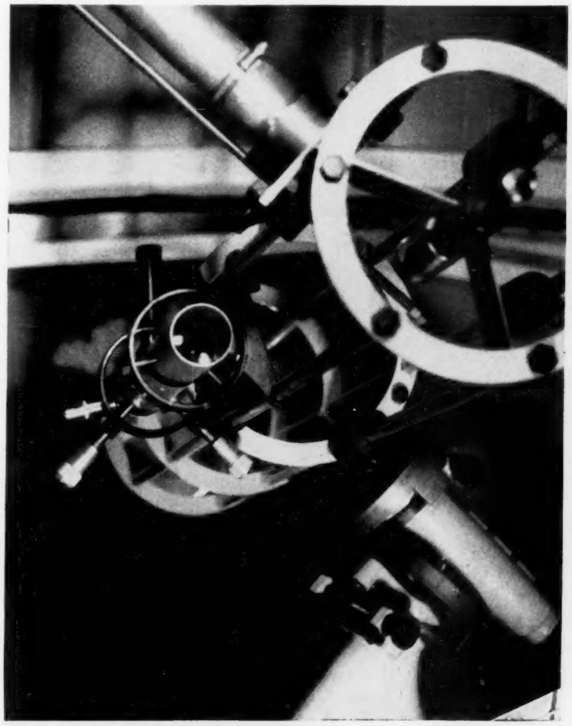


A close-up view of the Memphis Astronomical Society's 8-inch reflector. The tube is made up of 24 pipes, joined at the rings; the upper set of six pipes is stainless steel, and the spider and eyepiece assemblies can be slid up and down to change the focus for different optical arrangements. The tube extending out of the top of the picture contains a positive-lens arrangement to change the effective focal length of the system, and a motion-picture camera is attached at the far end of the tube. A finder is mounted at the left of the telescope. Photographs with this article supplied by the author.

Designing a Finder

Every astronomical telescope should have a finder. Occasionally, peep sights are placed on low-power, wide-field instruments, but the usual arrangement is a smaller telescope mounted on the main one.

Since the artificial satellite age began, there has been a trend among amateurs toward using low-power finders with large fields, for example 6x to 8x with 10° or 12° fields. Though such an optical system is good for observing bright satellites, it leaves much to be desired as a finder. The image scale is too small, which means that the sky background will be bright, and centering objects is less precise.

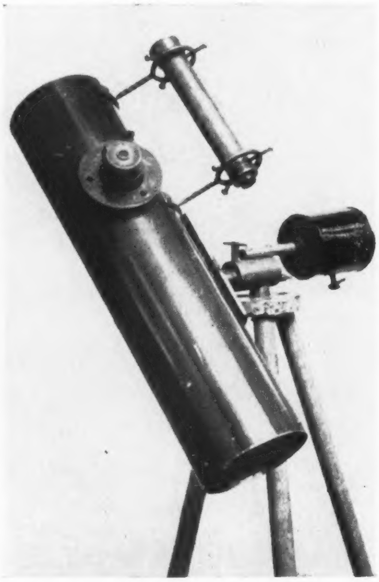
With too low a power, it may be difficult to recognize faint star clusters or galaxies. The practical observer soon learns that these objects are best seen with intermediate magnifications. The famous globular cluster M13 in Hercules shows much better contrast and resolution in a 6-inch reflector if a $\frac{1}{2}$- or $\frac{5}{8}$-inch eyepiece is used instead of a 1- or $1\frac{1}{4}$-inch. The same principle applies to finders, for which the advantage of medium power has often been overlooked by amateurs.

For all-round usefulness, a finder at 12x to 16x and having a field of 5° or 6° can be recommended. With large instruments, or for special work, 20x and a 3° field may be a good combination.

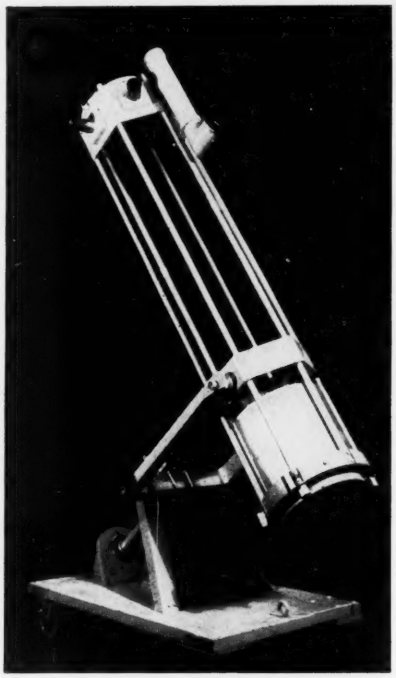
The angular diameter, d, of a finder's field of view depends on the focal length, F, of the objective and the linear diameter, S, of the focal-plane field covered by the eyepiece. The formula for the angular diameter in degrees is quite simple:

$$d = 57.3\,S/F.$$

A fairly close approximation for S is



Accurate alignment of the finder is easily obtained by mounting it as shown on this reflector, built by D. W. Rosebrugh, Meriden, Connecticut.



For convenient viewing near the zenith, an eyepiece diagonal is employed for the finder of this 8-inch reflector made by Warner Williams, Culver, Indiana, for the Swedish sculptor Carl Milles.

obtained by taking it as equal to the eyepiece's focal length, if this is not over $1\frac{1}{8}''$. Beyond that limit, the standard eyepiece mounting ($1\frac{1}{4}''$ in outside diameter) restricts the field of view. If S must be measured, use the eyepiece as a magnifier and read the interval visible on a finely divided ruler. With large Erfle oculars, a field diameter of 1.7" is possible, which with a short-focus objective can give the 12° coverage of a satellite telescope.

In designing a finder, good light grasp is an important consideration. To achieve this, the aperture should be as large as practicable. In my experience, the minimum useful diameter of the objective is about $1\frac{1}{2}''$, and 2" is better. Since commercial lenses of the latter size are readily available, we shall assume a 2-inch free aperture in the rest of this discussion.

Another light-controlling factor is the size of the exit pupil. For a simple two-element optical system, this is the diameter of the Ramsden disk formed behind the eyepiece, which equals the aperture divided by the magnification. The higher the power, the smaller the exit pupil, and the smaller the bundle of light reaching the eye. If the magnification is too low, the exit pupil may be larger than the actual size of the pupil of the observer's eye — the light that cannot enter the eye is wasted.

Rich-field telescopes and night binoculars are usually designed to have an exit-pupil diameter of about seven millimeters or 0.28", this being the pupil size

of a fully dark-adapted eye. In actual practice, however, the eye seldom attains this ideal condition, and light may be wasted with such a large exit pupil. A size of 0.20″ is excellent for finders, or even 0.125″ for the 3° field of a large reflector's finder. Hence, in a practical optical arrangement, we may use a 2-inch aperture, a field of 3° to 5°, and an exit pupil between 0.20″ and 0.10″. A number of finders meeting these specifications are shown in the accompanying table, the objective diameter being taken as 2″. For each combination are given the magnification, angular field, and the exit-pupil diameter.

FINDER COMBINATIONS

Lens F.L. (inches)	*Ocular F.L. (inches)*	*Ocular Field (inches)*	*Magnifying Power*	*Field of View (degrees)*	*Exit Pupil (inches)*
10	5/8	5/8	16.0	3.6	0.125
10	3/4	3/4	13.3	4.3	0.150
11.8	5/8	5/8	18.9	3.0	0.106
11.8	3/4	3/4	15.7	3.6	0.126
11.8	1	1	11.8	4.8	0.170
13	3/4	3/4	17.3	3.3	0.116
13	1	1	13.0	4.4	0.154
13	1 1/4	1 1/8	10.4	5.0	0.192
15.4	1	1	15.4	3.7	0.130
15.4	1 1/4	1 1/8	12.3	4.2	0.163
20	1 1/4	1 1/8	16.0	3.2	0.125
20	1 1/4	1.7	16.0	4.9	0.125

Two of these combinations merit special notice as heavy- and light-weight finders with 5° fields. The first uses an objective of 20″ focus and a giant Erfle eyepiece to secure a magnification of 16. In the second, 10½x is obtained with a lens of 13″ focal length. However, any of the combinations will make an excellent finder, the choice depending on the personal preference of the user.

Hitherto we have been considering refracting instruments, but 3-inch or 4-inch reflectors can be very serviceable as finders. For example, a 4-inch f/6.25 mirror with a giant Erfle 1¼-inch ocular will give a field of about 4° and a power of 20. As the middle of the field of view is used most, for centering objects, some vignetting around the edges is not objectionable, and we may make the diagonal smaller than is needed to cover the 1.7″-diameter field lens, thereby reducing light losses. The Newtonian focal plane can also be located on or just outside of the finder's tube, to decrease the distance from the prime focus to the diagonal and further reduce the diagonal's size.

Suppose the 4-inch reflecting finder mentioned above has a tube 5″ in diameter, the diagonal being placed 3″ from the prime focus. Then, if the linear size of the field is 0.75″, the recommended maximum diagonal size is 1.20″. This will keep silhouetting and light scattering within reasonable limits. Not a few observers, though, may wish a diagonal as large as 1.50″ or even 1.75″ for this finder, in order to increase the light near the edge of the field. This is highly de-

sirable if the finder is to be employed for magnitude estimates of variable stars.

How is the midpoint of the finder field to be marked so that a sky object can be centered in it? There is a wide variety of reticles, each with its enthusiastic advocates. If crosshairs are used, their diameter should not be excessive. It is difficult to pick up a star in a high-power ocular of the main telescope if the finder has heavy wires together with a very low magnifying power. One advantage of fairly thick wires, however, is that they can be seen against the sky, without auxiliary illumination.

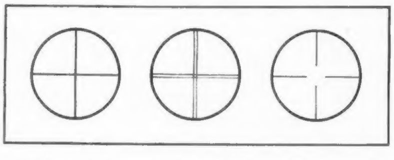
An amateur can easily construct his own cross reticle with fine wire, say 0.006" in diameter. Use two perpendicular pairs of wires, as shown in the diagram, to form a small square inside which a star can be centered. This avoids hiding the star, as can happen when a single heavy cross is employed.

Many of the reticles engraved on glass, commercially available as war surplus, are excellent in finders. These can be obtained with lines broken at the center, so that a faint sky object will be unobstructed.

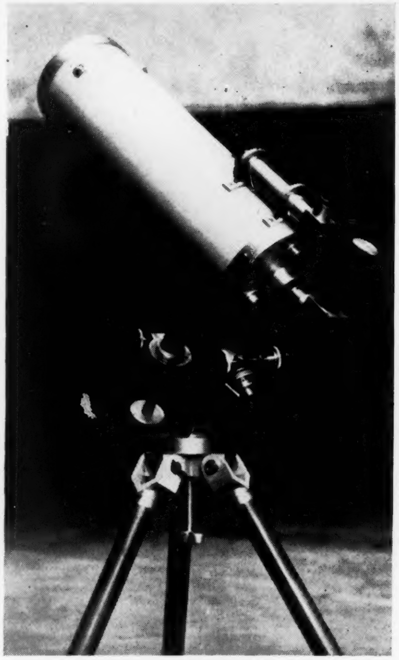
To illuminate a reticle, mount a small light bulb where its light can shine onto the crosshairs through a hole drilled in the finder tube. A piece of red cellophane or plastic over the hole is advisable, and the brightness of the light can be controlled with a rheostat or with two small pieces of polaroid, these being crossed and adjusted to the correct level of transmission. Often it has been suggested that luminous paint be put on the cross wires, but this method has not usually given satisfactory results, particularly if the wires are very thin.

The proper position for the reticle is an important matter, not always fully appreciated. In many finders, the reticle is permanently attached to the eyepiece, and the two are focused as a unit. However, the cross should lie simultaneously in the focal planes of the objective and eyepiece; otherwise parallax will result, and the cross will shift if the observer's eye is moved from side to side.

When used to view a celestial object, an astronomical telescope should be focused at infinity. Because of incorrect accommodation of the eye, however, the eyepiece is sometimes actually used as if it were a common magnifier, and the virtual image it forms is not at infinity but perhaps only a yard or two away. The solution of the problem is to put the reticle in the focus of the finder's objective, and then to focus the ocular without moving the reticle. Of course, if the eyepiece is of the Huygens type, with its field lens in front of the objective's focal plane (a negative ocular), then the cross wires must be placed inside the eyepiece.



Three different forms of reticles used in finders. Interrupted lines ruled on glass (right) allow a celestial object to be accurately centered without being blocked by the crosshairs.

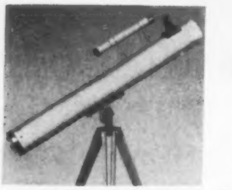


A diagonal eyepiece gives headroom in using a finder close to the telescope, as with this Cassegrainian reflector constructed by the late Allyn J. Thompson.

It is not difficult to set the reticle in the focal plane of the objective. The simplest way is to use the parallax effect itself. Focus the finder on some distant object and move the crosshairs back and forth in the tube until a setting is found where they remain fixed with respect to the object when the eye is moved from side to side.

A more precise method is to use the main telescope as a collimator. Focus it on a star or some other object at infinity, so it will give sharp definition only to parallel rays of light. Support the main telescope tube horizontally and before its front end mount the finder, likewise horizontal, with its objective toward the larger instrument. Remove the eyepiece from the finder and shine a light through it from back to front so that the reticle is seen in silhouette through the main telescope. In order for the reticle to appear sharp, the rays emerging from the finder objective must be parallel, that is, the reticle must be at the infinity focus of the objective. Slide the reticle supporting ring back and forth in the finder tube until the sharp image is seen, and then lock the ring in this position.

R. E. C.



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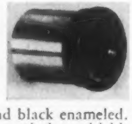

These are best for extremely high magnification (300 power with a 48"-f.l. objective). You get a wide, flat field — almost 3 times as much field as a Ramsden of the same power — excellent color correction and definition. Precision made of brass, chrome plated and black enameled. Inside is dead-black anodized with anti-glare shield.

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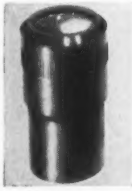
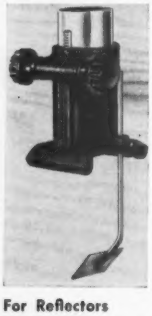


Mounted Kellner eyepiece, type 3. Two achromats, focal length 28 mm., eye relief 22 mm. An extension added, O.D. 1¼", standard for most types of telescopes. Gov't. cost $26.50.

Stock #5223-Y........$7.95 ppd.

Rack & Pinion Eyepiece Mounts



Real rack-and-pinion focusing with variable tension adjustment; tube accommodates standard 1¼" eyepieces and accessory equipment; lightweight aluminum body casting (not cast iron); focusing tube and rack of chrome-plated brass; body finished in black wrinkle paint. No. 50,077-Y is for reflecting telescopes, has focus travel of over 2", and is made to fit any diameter or type tubing by attaching through small holes in the base. Nos. 50,103-Y and 50,108-Y are for refractors and have focus travel of over 4". Will fit our 2⅞" I.D. and our 3⅞" I.D. aluminum tubes, respectively.

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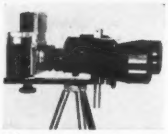

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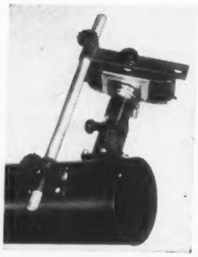
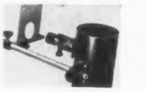


Bracket attaches permanently to your reflecting or refracting telescope. Removable rod with adjustable bracket holds your camera over scope's eyepiece and you're ready to take exciting pictures of the moon. You can also take terrestrial telephoto shots of distant objects. Opens up new fields of picture taking!



SUN PROJECTION SCREEN INCLUDED

White metal screen is easily attached to holder and placed behind eyepiece. Point scope at sun, move screen to focus . . . and you can see sunspots!

All for the low, low price of $9.95

Includes brackets, 28¾" rod, projection screen, screws, and directions. Aluminum . . . brackets black crinkle painted.

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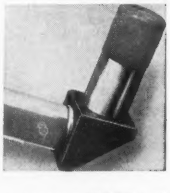
PRISM STAR DIAGONAL



For comfortable viewing of the stars near the zenith or high overhead with refracting telescopes using standard size (1¼" O.D.) eyepieces, or you can make an adapter for substandard refractors. Contains an excellent high-quality aluminized right-angle prism. The tubes are satin chrome-plated brass. Body is black wrinkle cast aluminum. Optical path of the system is about 3½".

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Same as above except contains Amici roof prism instead of usual right-angle prism. Thus your image is correct as to right and left, making it excellent for terrestrial viewing.

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SHEET-FILM CAMERA

Uses sheet film 2¼" x 3¼" size. Camera box size is 3" x 4" x 5".

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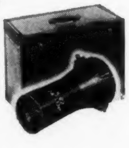

Big variety . . . at a fraction of Gov't. cost! f/6, 24" f.l., with diaphragm and lens cone. Used. Weight 25 lbs.

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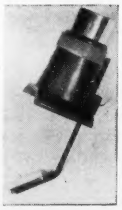

Here is an economical plastic slide-focus eyepiece holder for 1¼" O.D. eyepieces. Unit includes 3"-long chrome-plated tube into which your eyepiece fits for focusing. Diagonal holder in illustration is extra and is not included.

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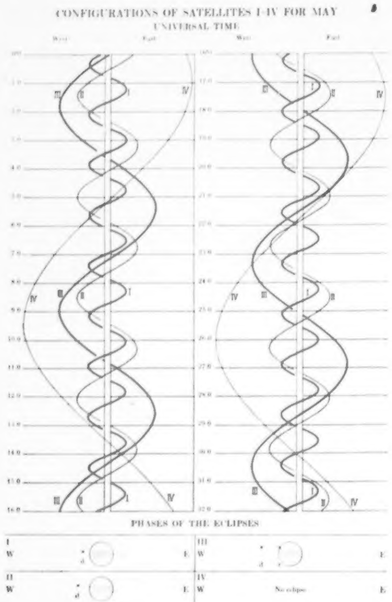
EDMUND SCIENTIFIC CO.

CELESTIAL CALENDAR

Universal time (UT) is used unless otherwise noted.

The Configurations of Jupiter's Four Bright Moons

THIS CHART, reproduced from the *American Ephemeris and Nautical Almanac*, shows the changing positions of Jupiter's four bright satellites throughout the month. The form of these graphical predictions is different from that in



earlier years. Formerly, positions were given for one time only of each day; now each satellite is represented by a curve, making it easier to tell its place for any time on any date.

The four curving lines labeled with Roman numerals are for **I**, Io; **II**, Europa; **III**, Ganymede; and **IV**, Callisto, respectively. The location of Jupiter's disk is marked by a pair of vertical lines. When a satellite passes in transit across the planet's disk, its curve crosses the pair of lines. If a moon is invisible because it is in occultation behind Jupiter, or is eclipsed by Jupiter's shadow, the curve is broken.

For successive dates, the horizontal lines mark 0^h Universal time, corresponding to 7 p.m. Eastern standard time, or 4 p.m. Pacific standard time, on the preceding day. The vertical scale is such that one millimeter is equal to about six hours. In the chart, west is to the left, corresponding to the view in an inverting telescope, for a Northern Hemisphere observer.

As an example of the use of the chart, consider someone looking at the satellites at 4 a.m. Pacific standard time on May 2nd. This corresponds to 12^h UT on the 2nd, that is, halfway between the lines for May 2.0 and 3.0. Reading the diagram, we note that the objects visible are, from west to east, **III**, Jupiter, **II**, and **IV**, whereas **I** is invisible. At the time in question, **III** and **IV** are approaching the planet, while **II** is receding from it, having emerged from occultation shortly before.

It is easy to tell from the diagram when a particular satellite is at elongation, that is, farthest east or west of the planet, or when all four moons will be on the same side of Jupiter. The latter phenomenon takes place, for example, on the morning of May 23rd.

Four smaller diagrams at the foot of the picture are designed to aid the observer of eclipses of the satellites. In each case, the point **d** marks the position of the satellite, relative to Jupiter, when it disappears into eclipse. Moons **I** and **II** are behind the planet when their eclipses end, but reappearances of **III** from eclipse are visible, at the point labeled **r**. Satellite **IV** does not pass through the planet's shadow during May.

The *American Ephemeris* for 1960, from which this illustration was taken, contains much additional information about the satellites of Jupiter, including detailed predictions of their eclipses, occultations, transits, and shadow transits. Observations of these phenomena can be made with small telescopes.

MAY METEORS

This year's Eta Aquarid meteor shower occurs under fairly favorable conditions, the moon being near first quarter at shower maximum – May 4th. With good sky conditions, an observer can expect to see about 20 meteors per hour. On the 4th the radiant will be near Zeta Aquarii; it will move northeastward a degree a day. Peter M. Millman cites 18 days as this shower's normal duration, that is, the interval during which the shower strength is at least a quarter that of its maximum.

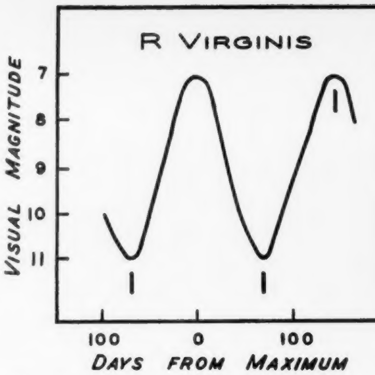
W. H. G.

MINIMA OF ALGOL

May 2, 5:38; 5, 2:27; 7, 23:16; 10, 20:05; 13, 16:54; 16, 13:43; 19, 10:32; 22, 7:21; 25, 4:10; 28, 0:59; 30, 21:47.

June 2, 18:36; 5, 15:25; 8, 12:14.

These minima predictions for Algol are based on the formula in the 1953 *International Supplement* of the Krakow Observatory. The times given are geocentric; they can be compared directly with observed times of the star's least brightness.



Typical brightness changes of R Virginis are portrayed in this mean light curve based on AAVSO observations, and reproduced from "Studies of Long Period Variables."

R VIRGINIS

LOCATED west of Delta and Epsilon Virginis and forming a nearly equilateral triangle with them is the famous long-period variable R Virginis, at right ascension 12^h $36^m.0$, declination $+07°$ $16'$ (1950 co-ordinates). The average light cycle of this star takes 145 days, between the magnitude limits 6.9 and 11.5. Observers who look for this orange object near the scheduled date of maximum brightness, June 3rd, may expect to find R as much as half a magnitude brighter or fainter than 6.9. It should be easy to locate with binoculars and a star chart.

The variability of R Virginis was detected as long ago as 1809 by K. L. Harding, at Göttingen, Germany. At that time he was compiling a star atlas, and may have first noted this variable during his charting. Harding is best remembered as the discoverer of Juno, the third asteroid, on September 1, 1804.

VARIABLE STAR MAXIMA

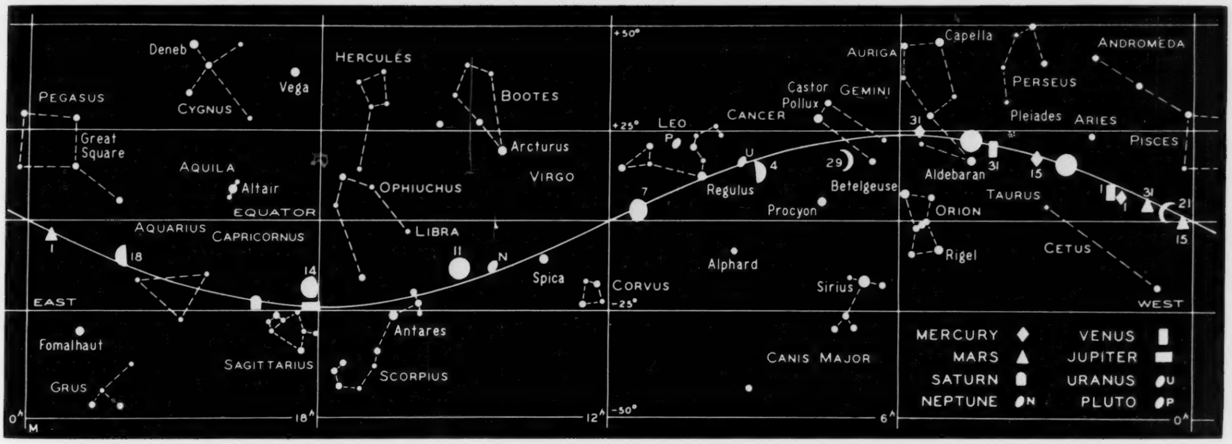
May 4, T Herculis, 180531, 8.0; 5, V Bootis, 142539, 7.9; 7, S Coronae Borealis, 151731, 7.3; 8, S Pictoris, 0508**48**, 8.1; 10, R Phoenicis, 2351**50**, 8.0; 23, U Orionis, 054920a, 6.3; 31, S Hydrae, 084803, 7.8.

June 3, R Virginis, 123307, 6.9; 4, S Herculis, 164715, 7.6; 5, RU Sagittarii, 1951**42**, 7.2; 9, T Centauri, 1336**33**, 5.5.

These predictions of variable star maxima are by the AAVSO. Only stars are included brighter than magnitude 8.0 at an average maximum. Some, but not all of them, are nearly as bright as maximum two or three weeks before and after the dates for their maxima. The data given include, in order, the day of the month near which the maximum should occur, the star name, the star designation number, which gives the rough right ascension (first four figures) and declination (bold face if southern), and the predicted visual magnitude.

UNIVERSAL TIME (UT)

TIMES used in Celestial Calendar are Greenwich civil or Universal time, unless otherwise noted. This is 24-hour time, from midnight to midnight; times greater than 12:00 are p.m. Subtract the following hours to convert to standard times in the United States: EST, 5; CST, 6; MST, 7; PST, 8. To obtain daylight saving time subtract 4, 5, 6, or 7 hours, respectively. If necessary, add 24 hours to the UT before subtracting, in which case the result is your standard time on the day preceding the Greenwich date shown. For example, 6:15 UT on the 15th of the month corresponds to 1:15 a.m. EST on the 15th, and to 10:15 p.m. PST on the 14th.



THE SUN, MOON, AND PLANETS THIS MONTH

The sun, on the ecliptic, is shown for the beginning and end of the month. The moon's symbols give its phase roughly, with the date marked alongside. Each planet is located for the middle of the month or for other dates shown. All positions are for 0^h Universal time on the respective dates.

Mercury comes to superior conjunction with the sun on May 17th, moving into the evening sky. It is lost in the solar glare until the end of the month, when it may be possible to glimpse it low in the west just after sundown.

Venus is a morning object, but too near the sun to be observed this month.

Mars in mid-May is a fairly bright object in Pisces, its magnitude being +1.2. Rising about two hours before sunup and visible low in the east, it is still too far from the earth for detailed telescopic study, being only 5".3 in apparent diameter on the 15th. Mars will be occulted by the moon on May 20th for observers in the East Indies, northern Australia, and the Pacific area. The planet reaches the perihelion point of its orbit on the 26th.

Jupiter is in Sagittarius, rising about three hours after sunset on the 15th and visible the rest of the night as a brilliant yellow object of magnitude −2.1. During the month, the planet's telescopic disk increases from 43" to 46" in equatorial diameter. On the evening of May 13-14, the moon will pass 5° north of Jupiter. A chart giving the positions of Jupiter's four bright satellites is on the facing page.

Saturn in midmonth rises about 11 p.m., local time, and can be seen in Sagittarius, about 15° east of Jupiter. Its magnitude is +0.6. A telescope will show the ring system, 39".8 in extent, with its plane tipped 23°.8 to the line of sight; the ball of the planet is 15".8 in polar diameter. The moon will pass 4° north of Saturn on the night of May 14-15.

Uranus arrives at eastern quadrature to the sun on May 7th, when it will cross the meridian about an hour before sunset. Now in the western evening sky, near the Leo-Cancer boundary, this 6th-magnitude planet is readily visible with binoculars. A finder chart for Uranus appeared on page 191 of the January issue.

Neptune is close to the Libra-Virgo border in May, and on the 15th crosses the meridian about an hour before midnight, local time. Users of small telescopes can locate this 8th-magnitude planet with the aid of the finder chart printed here in January.

W. H. G.

MINOR PLANET PREDICTIONS

Vesta, 4, will be brighter than visual magnitude 7 from April until near the end of September, and thus readily found with binoculars. It will gradually increase in brilliance from magnitude 6.5, early in May, to 6.0 at opposition on July 2nd, and then slowly fade to 7.6 by the first week in November.

Retrograde motion begins May 21st, and lasts until August 14th. During the entire interval given below, this asteroid will be in Sagittarius.

The following listing is a continuation of one on page 254 of the February, 1960, issue. These predicted positions, for the epoch 1950.0, have been abridged from the *American Ephemeris.*

May 6, 19:08.6 −18-38; 16, 19:11.9 −18-52; 26, 19:11.9 −19-17. June 5, 19:08.6 −19-53; 15, 19:02.1 −20-40; 25, 18:53.2 −21-35. July 5, 18:43.1 −22-31; 15, 18:33.4 −23-24; 25, 18:25.4 −24-12.

August 4, 18:20.3 −24-52; 14, 18:18.5 −25-24; 24, 18:20.2 −25-50. September 3, 18:25.2 −26-09; 13, 18:33.1 −26-21; 23, 18:43.5 −26-26. October 3, 18:56.0 −26-23; 13, 19:10.3 −26-11; 23, 19:25.9 −25-50. November 2, 19:42.7 −25-20.

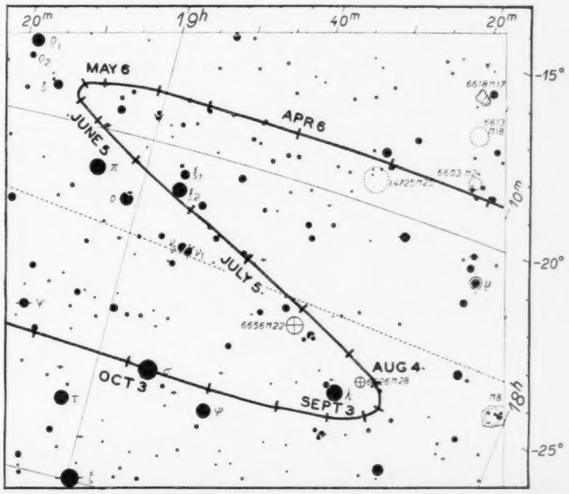
Juno, 3, 10.2. May 16, 17:40.5 −5-32; 26, 17:33.7 −4-58. June 5, 17:25.7 −4-34; 15, 17:17.1 −4-21; 25, 17:08.7 −4-22. July 5, 17:01.2 −4-35. Opposition on June 11.

After the asteroid's name are its number and the approximate visual magnitude expected at opposition. At 10-day intervals are given its right ascension and declination (1950.0) for 0^h Universal time. In each case the motion of the asteroid is retrograde. Data are supplied by the IAU Minor Planet Center at the University of Cincinnati Observatory.

MOON PHASES AND DISTANCE

First quarter	May 4, 1:01
Full moon	May 11, 5:43
Last quarter	May 17, 19:55
New moon	May 25, 12:27
First quarter	June 2, 16:02

May	Distance	Diameter
Perigee 12, 18^h	224,000 mi.	33′ 09″
Apogee 28, 4^h	252,400 mi.	29′ 25″
June		
Perigee 10, 2^h	222,100 mi.	33′ 26″



The path of the bright asteroid Vesta among the stars of Sagittarius to October, 1960. The faintest stars charted here are of visual magnitude 7.75. The base map is adapted from the Skalnate Pleso "Atlas of the Heavens."

STARS FOR MAY

The sky as seen from latitudes 30° to 50° north, at 9 p.m. and 8 p.m., local time, on the 7th and 22nd of May, respectively. For other dates, add or subtract ½ hour per week.

At chart time, the Big Dipper and Canes Venatici (the Hunting Dogs) are high overhead. Near the latter constellation is the glittering swarm of stars that form the Coma Berenices cluster, a beautiful sight on a clear, dark night. Look in the south for the conspicuous quadrilateral of Corvus the Crow.

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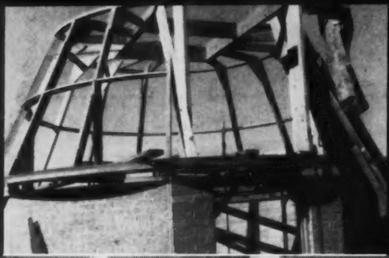
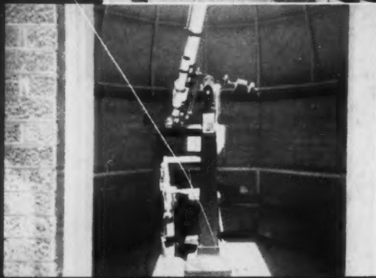
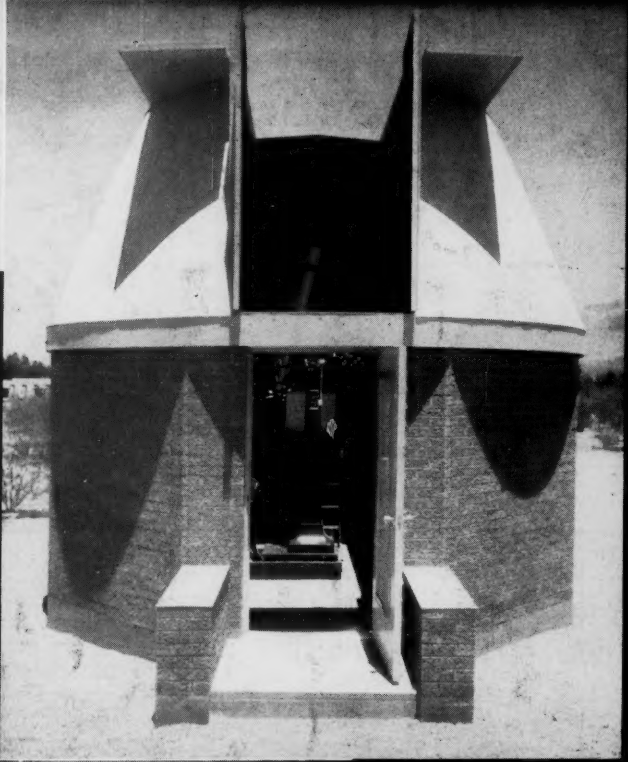


Dome framework of Hubbard Observatory under construction. Note 15′-circular steel rail, spotwelded to 3/16″ steel plate capping the octagonal wall.

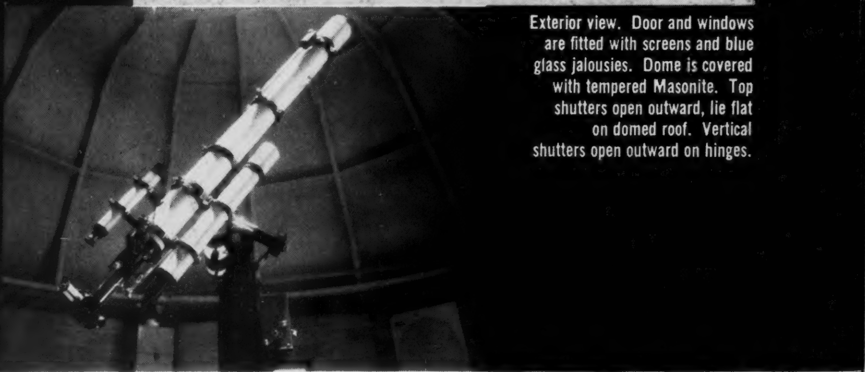


Interior view, showing adjustable observer's chair which swivels on casters around pier of 4″ Model 166 UNITRON.

Bela Hubbard builds a "dream house" for his UNITRON



Exterior view. Door and windows are fitted with screens and blue glass jalousies. Dome is covered with tempered Masonite. Top shutters open outward, lie flat on domed roof. Vertical shutters open outward on hinges.



Note structural details of dome interior.

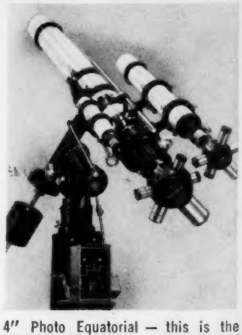
Bela Hubbard, of Tucson, Arizona, is one amateur astronomer who believes you don't have to be a millionaire to view like one.

To prove it, he built the observatory you see on this page. Presently, it houses the new 4″ UNITRON Equatorial Refractor he recently bought. Eventually, it will house the 6″ UNITRON he plans to own some day.

From its steel-reinforced concrete foundation, to its double-thick masonry walls, to its 15′-diameter turret dome, Hubbard Observatory is clearly a labor of love — a thing of beauty and a joy practically forever. Yet the cost was surprisingly low.

After building his "dream house", Mr. Hubbard sat down and wrote us all about it. He told us how the job was planned; the problems he solved; the materials he used; how long the job took; and how much it cost for labor and materials.

Now, we're not in the observatory business. But it occurred to us that a lot of amateur astronomers might be interested in Mr. Hubbard's "how-to" report. So with his permission, we've had the complete, illustrated report printed up as a guide and idea-source you could adapt to your own needs and equipment. Feel free to send for a copy. Also available, free, UNITRON'S Observer's Guide and Catalog. Just write:



4″ Photo Equatorial — this is the UNITRON Model 166 presently housed in the observatory. With fixed pier, clock drive and astro-camera, $1280.

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SEE PAGES 436 AND 437 FOR MORE ABOUT UNITRON.

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